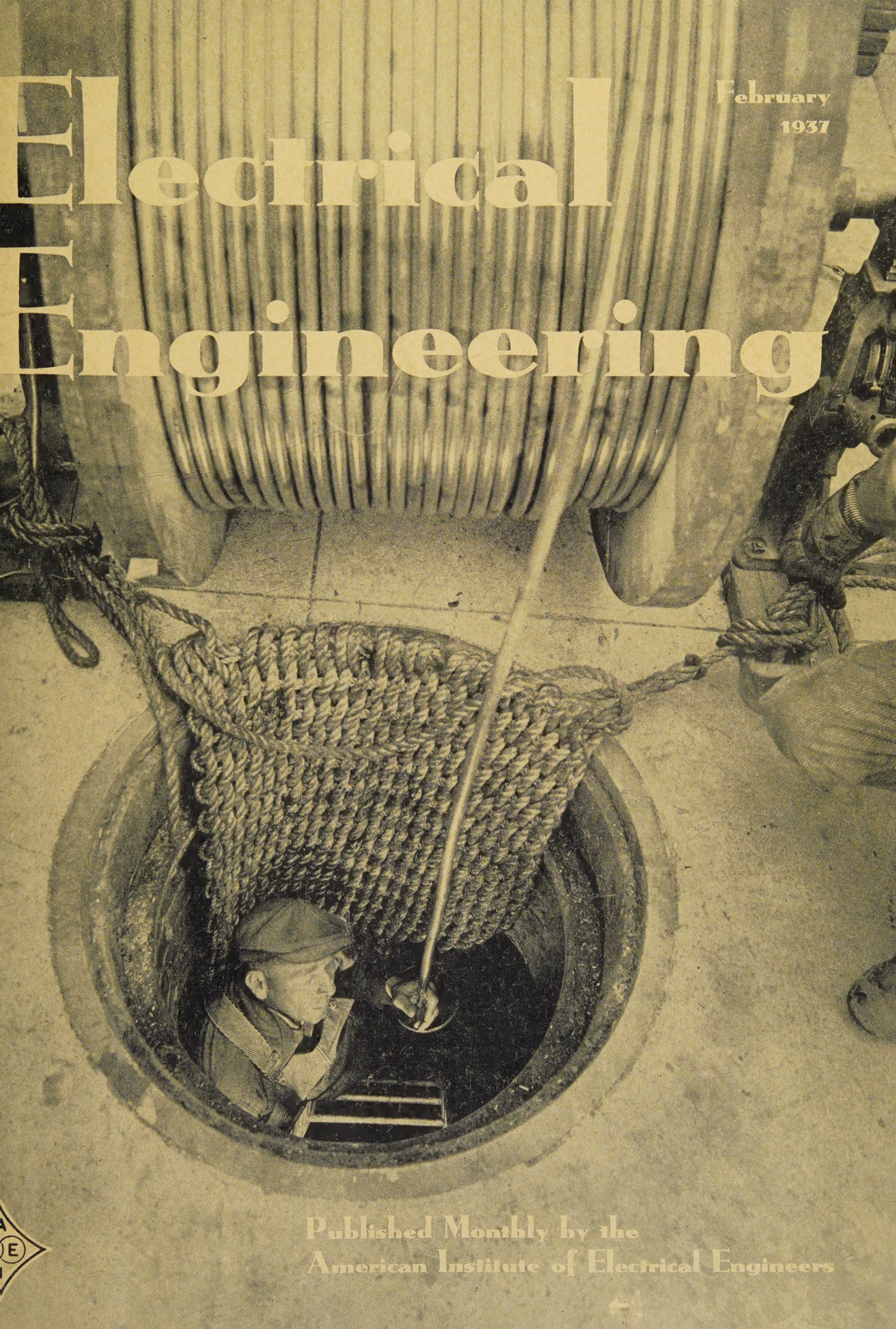
Electrical Engineering

February
1937



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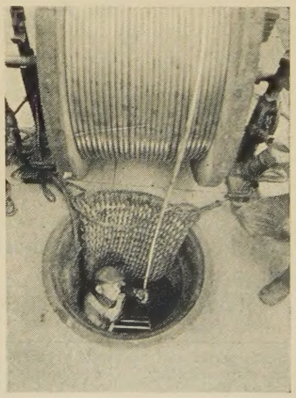
The Cover

Coaxial communication cable being drawn into conduit

Photo courtesy New Jersey Bell Telephone Co.



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High Lights

Water-Level Control. Control of the water level in a model of the Cape Cod (Mass.) Canal and the automatic recording of water level at several points during studies of flow were accomplished electrically by utilizing the capacitance between the water itself and a plate suspended above it, together with suitable vacuum-tube amplifiers, grid-controlled arc-discharge tubes, and Selsyn motors (*pages 237–44*).

Engineers and Economics. Successful economic planning is most hopefully to be looked for if the planners are guided by the approach and method characteristic of an engineer. However, individuals combining this with other essential traits are regarded as rare (*pages 206–07*).

Japanese Progress. The characteristics of the Japanese people, their educational system, and cultural and industrial development are reported by a visitor to Japan who finds that country well-equipped to compete with the western world (*pages 208–15*).

Electrical Machinery. Reactance of end connections and eddy currents in rotor bars are the subjects of 2 papers in this issue. In one the use of image conductors in iron, of Rayleigh insulating partitions, and of images of conductors in these partitions are shown to afford an attack on the problem of end-connection reactance (*pages 257–60*). The other paper shows that from oscillograms of eddy currents in the rotor bars of a squirrel-cage induction motor, the magnitude of the power loss caused by eddy currents, and its variation with load, may be determined (*pages 253–6*).

Switchboards. The power plant at Boulder Dam has been equipped with switchboards notable for their size and for the combination of designs and methods that heretofore have been used individually but seldom together (*pages 224–36*).

Lightning Investigation. Data obtained from the measurement of lightning currents in tower structures, counterpoises, and ground wires on a 132-kv line indicate that stroke currents rarely exceed 150,000 amperes and that adequate shielding of lines at station entrances is necessary (*pages 245–52*).

Stability. A comprehensive review of th subject of stability of large power system is presented in a report of an AIEE sub committee. A summary of the recent prac tices regarding stability features of man power systems throughout the Unite States is included (*pages 261–82*).

Tube Nomenclature. A committee of th American Standards Association is attempt ing to simplify the nomenclature of elec tronic tubes, and toward that end has ob tained an agreement by 2 large manu facturers to abandon trademark rights t several names. A tabulation indicatin the initial step is given in this issue (*pag 284*).

Unemployment Among Engineers. Unem ployment data from 52,589 engineer throughout the United States, obtained i the 1935 survey of the engineering profes sion conducted by the United States Burea of Labor Statistics shows that more tha 1/3 of all engineers reporting were unem ployed at some time during the year 1929–34; half of these were unemploye for more than a year. The largest pro portion unemployed at any one time wa about 11 per cent (*pages 216–23*).

Correction. An error in photoengraving shifted from its correct position the center vertical scale of figure 11 of the paper "Pole Flexibility as a Factor in Line Design" by Howard P. Seelye and Myron Zucker, as reproduced on page 97 of the January 1937 issue. The corrected figure is shown here.

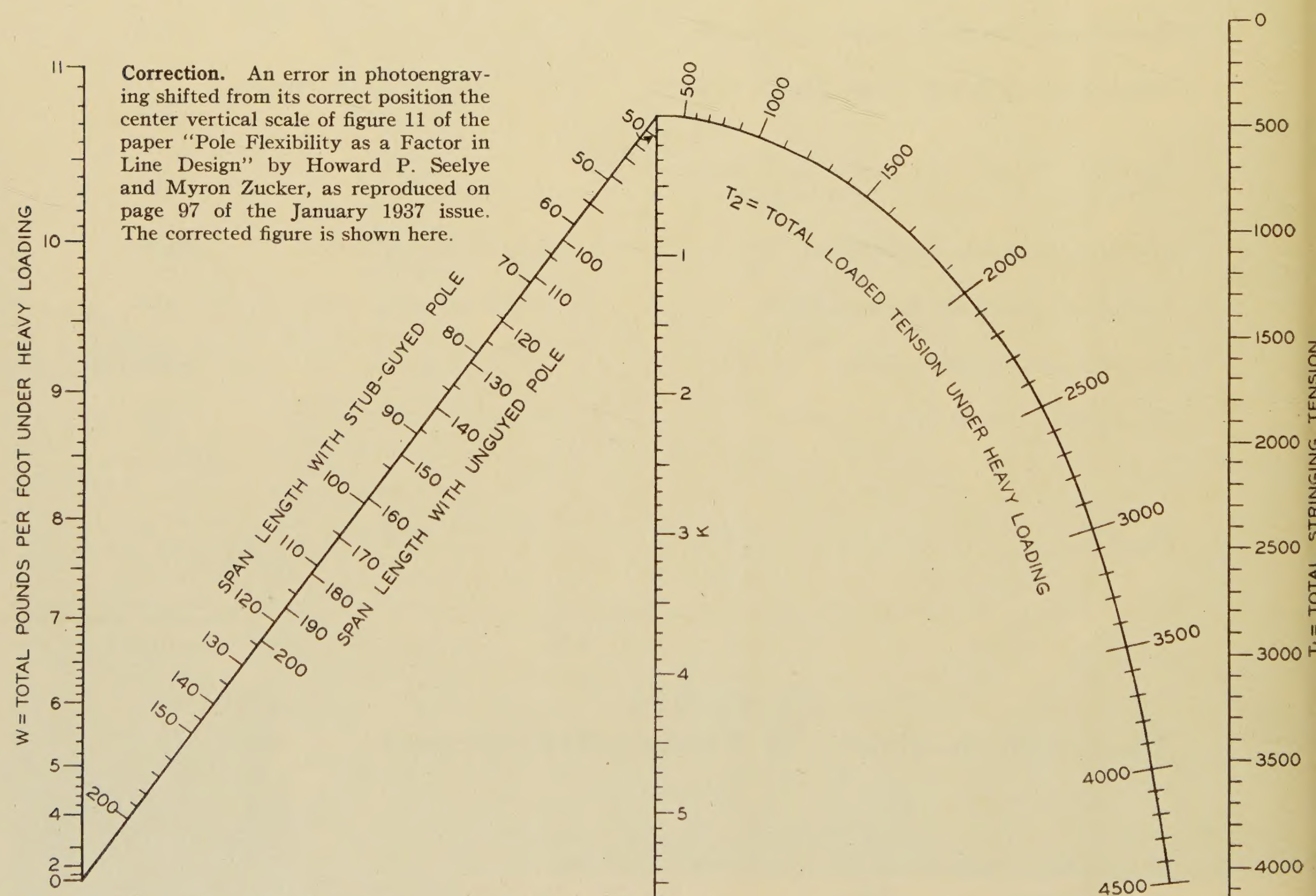

Fig. 11. Simplified chart for special conditions

Initial sags approximately 2 per cent of span
$p = 500$ for pole only; $p = 2{,}500$ for pole and stub

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..LUME 56, NO. 2 FEBRUARY 1937

The Challenge of 1937

..36 is now history. Whatever we have accomplished, ..r failed to accomplish, is written into the records ..nd we cannot change it. The engineer is interested ..story as a guide to the future, but what most intensely ..ests him is that which he may accomplish in the ..e. Every keen-minded member of the American ..tute of Electrical Engineers is greatly interested in ..uture accomplishments of the organization.

..e are not satisfied with the performance of our ..nization, and I hope that we never will be. The ..test stimulus to future accomplishment is a sane and ..hy dissatisfaction with the past.

..though not satisfied, we can secure a certain degree ..omfort through comparison. I think that we will suffer in comparison with other technical societies. .. too wish to accomplish more than they have in the .. In a broader sense, are we entirely satisfied with ..rs throughout the world? Are we entirely satisfied affairs in our own country? Yet is it not the best ..try in which we can live? Likewise is not our ..nization the best one available to us for our profes..l advancement? Our problem is to make it the best ..nization possible.

..ith privilege comes responsibility. It is the privilege ..e Institute to represent professionally the electrical ..neers of America, and this high privilege implies a responsibility of which we should ever be conscious. ..uring the last year, have we adequately represented electrical engineering profession in our technical ..ities? I think we have, but I know that we can do ..r in 1937. A greater participation of the Sections ..e national technical activity is desirable. This does ..mean that each Section must set up a technical com..e corresponding to each of the national technical ..mittees, but rather that each Section has the privilege ..ecting 1, 2, or more technical committees in the work ..hich that Section is particularly interested. This ..rtunity is a real challenge to each Section for 1937. ..uld suggest that the Sections start by selecting the ..echnical committee in the work of which they are most interested, and organize within the Section a corresponding technical committee. In this way it is possible for every Section to contribute to the national technical activity. The chairman of such a Section technical committee would be a very logical nominee by the Section for membership on the corresponding national technical committee the following year.

Has the Institute in 1936 effectively embraced its opportunity in advancing the professional standing of its members? Here lies another challenge for 1937.

Should there be a gradual and intelligent broadening of the sphere of Institute activities? This deserves very earnest consideration. As one example of what can be accomplished, I was very favorably impressed by a paper "The Engineer's Responsibility to Society" which was presented by a student member at a recent Branch conference held in Pittsburgh, Pa.

Are we satisfied with the 1936 record of members added to our rolls? Before answering, let us consider why a professional engineering society desires addition to its membership. If there be electrical engineers who are qualified for membership but who are not members, the society will be more truly representative of the electrical engineering profession if they were offered the opportunity of joining. If they would then participate in the activities of the organization, it is obvious that the organization would more nearly measure up to its opportunities. The increased financial support from such new members would enable the organization more successfully to carry on all its work. The challenge of 1937 will not be successfully met unless every qualified electrical engineer is offered the opportunity of enrolling in our ranks.

I firmly resolve to do all in my power to meet the inspiring challenge of 1937, and I ask every one of our more than 15,000 members to make the same resolution.

PRESIDENT AIEE

Engineers and Economics

By MORRIS E. LEEDS
FELLOW AIEE

The characteristics of engineering that should give the engineer a stronger sense of economic and social responsibility than is sometimes felt by those in other professions are discussed in this article, which suggests that an engineering approach should be made to economic problems.

MANY individual engineers undoubtedly feel a peculiar sense of obligation to make some contribution to the solution of our economic difficulties, and I think we may safely say that engineers collectively in their organizations share that feeling. The individual sense of responsibility is manifested by numerous writings and statements of men in the profession. As a result of collective efforts we have had the reports of the committee of the American Engineering Council on the relation of production, distribution and consumption, out of which grew a real, though unsuccessful, effort on the part of the Engineering Foundation and the American Engineering Council to plan for such work under engineering auspices with an even broader committee, including representatives of labor and the public.

Of course, engineers are not the only groups that have made such efforts. Many reports addressed to aspects of economics have been issued, representing trade organizations, chambers of commerce, etc., but these have generally concerned themselves quite narrowly with the needs of those for whom they spoke and have assumed, if they considered it at all, that the general welfare would coincide with their own. They do not show the disinterested breadth of view which led the engineers' committee to state as its objective:

"The selection and recommendation of such governmental, financial, and business policies as will maintain in the United States a standard of living that is high, broadly distributed, and free from severe fluctuations."

I wish to discuss particularly those characteristics of engineering which in my judgment should give the engineer a stronger sense of economic and social responsibility than is felt by his brethren of industry and the other professions.

There are those who say that his responsibility is a natural consequence of his conspicuous success. Pursuing his work along the lines of the definition now more than a century old—"the art of directing the great sources of power in nature for the use and convenience of man"—the engineer has done his full part in providing us very rapidly with such a wealth of machinery for producing goods and services and providing transportation and communication, that this good fortune has come on us more quickly than we have learned to manage it, and, lacking that management skill, has become temporarily and in part a misfortune. It is argued that the engineer having contributed so largely to this condition now has the obligation to extend his art to the field of social and political economy so as t make his other contributior an unmixed blessing. Ther is something in this viewpoin but responsibility in that sens belongs also to scientists, ir ventors, perfecters of manage ment, and other innovator: To my thinking, the chief reason for the engineer's re sponsibility lies in his possession of an approach an method which have been so perfected that they ar uniquely valuable for producing practical results unde imperfectly understood and complicated circumstance where, as in the economic realm, traditional method fail and it is not obvious how to proceed.

The essentials of the engineering approach and methoc I take it, are these:

A clear conception and precise statement of the objective to b achieved.

A consideration, as thorough as practicable, of all the factors- be they physical, social or psychological—which will influence c may be employed in getting the desired results; and on the bas of this knowledge—

The formulation of the most effective plans for achieving resul that can be developed in the allowable time.

This may seem to many of you to be little more tha elementary common sense. Good sense I believe it to b but common I think it is not.

I have just now referred to this approach and metho as uniquely characteristic of the engineer, and takin these steps all together I believe they are. Others ma clearly conceive and precisely define their objectives, bu in practical affairs that is rare.

Business men for the most part work in fields wher experience, tradition, and the pressure of circumstanc serve to guide their plans and policies.

Scientists weigh the facts pertinent to their subjec perhaps more thoroughly than do engineers, but the seek perfection of classification and description, extensio of knowledge and theory, rather than the developmer of workable plans—and that is a highly significant dis tinction. Moreover, they are not hampered by a dat on which the report is due, while the engineer is almos always limited in that respect. I have heard it sai recently that a recognized authority, who has publishe extensively on the business cycle, has said that h needs 5 years more before he will be in a position t

Written especially for Electrical Engineering, based on a paper present at the corporation dinner of the Brooklyn Polytechnic Institute on June 1 1936. Manuscript submitted January 7, 1937; released for publication Jan ary 7, 1937.

Morris E. Leeds is president of the Leeds and Northrup Company, Phil delphia, Pa.

k definitely about controls. Contrast that viewpoint :h, let us say, a bridge engineer. His plans must be .dy in a certain time; and if a new material which omises lighter and better structure cannot be suffi- ntly time-tested to be used safely, he must plan a ıvier one known to be safe.

[know of no science, trade, or profession other than gineering that has perfected an approach and method ıt are so clearly right for dealing with our muddled onomics.

Let me explain at this point that when I speak of onomic plans I am not talking of something new and ange. Any measure for getting an economic result, :h as a tax bill or a tariff act, is an economic plan; d any discussion by which such bills are formulated is onomic planning of a sort.

We do not want planning of the Russian type, or except emergencies, even that of our own War Industries ard. With us economic plans will become effective ly as they commend themselves to our people and their islative representatives. Planning for democratic ac- otance *is* going on continuously in an unorganized way rough public discussion, in magazines, pamphlets, and oks, and a great amount of useful educational work is ing done which ranges in value from the ephemeral d trivial to the publications of such men as Maynard ynes and those of such bodies as the Brookings Insti- :ion and the National Bureau of Economic Research. t in spite of this extensive discussion, we still seem far m agreement as to the best means of dealing with r very serious unemployment situation, for instance, d this is only one of a number of important subjects which we do not have a united or settled opinion. t me illustrate by reminding you of a few of them.

w can taxes be levied so as to bring in the desired revenue and tribute the burden equitably?

w shall they be apportioned between the states and the nation?

ould taxes be used for other purposes than to raise revenue, as import taxes are used to encourage domestic production?

n they be planned to moderate instead of intensify the business le?

ll prosperity be enhanced by a policy which excludes practically rything that we can produce in our own country, or by one that ourages a large exchange with other countries; or if by some ermediate position, how shall that position be determined?

w are we to maintain balance between production and consump- n; between agriculture and industry, etc.?

various stages of national wealth, what proportion of the total uld be expended publicly by government?

at about foreign debts, credit and finance?

[t is in connection with this complex situation that onomic plans are to be developed, and in order to be ective they must have popular democratic acceptance. epeat that success is most hopefully to be looked for if planners are guided by the engineer's approach and thod. Thus guided:

They would clearly envisage their objective and would probably e it in some such language as the engineers did, that is, a level of national prosperity that is high, widely and fairly distributed, and free from serious interruptions.

2. They would take into consideration all the factors, be they physical, social, or psychological, which will influence or may be employed in getting the desired results. This will include an understanding of the conditions necessary for getting popular acceptance.

3. On the basis of the available knowledge they would present the best practical plan for achieving the results that the time available permitted. The time factor is important. The plan must be one that can be put through at some specific time, and one that will work after it is enacted, with conditions as they are.

It may be questioned whether those who have attained proficiency in some branch of their profession will thereby be best fitted to translate this fundamental engineering attitude to such an alien field as economics. An essential condition is that all the pertinent factors, including the social and the psychological, be taken into consideration. Perhaps the engineer, who has become accustomed to and has chiefly dealt with the dependable phenomena of the physical world, would thereby be unfitted for dealing with economic phenomena in which human will and emotion and mass psychology play so large a part. The practice of engineering will not in itself familiarize one with the vast body of economic fact and theory.

This is my conception of the kind of men who would best qualify for economic planning. They will be men who understand the engineering approach and method, whether trained in the profession or out of it. They will be men who have so risen above any particular industry or profession, through which they have achieved eminence, that they will be able to see society and its needs as a whole. They should have the steadiness and dependa- bility which come from successful adjustment of their own affairs to practical conditions, and, along with those qualities, should be marked by a high degree of social idealism. A rare type! There are many men who have the first of these qualifications; many who have the second; few who combine them. Of the few men whom I know or know about who seem to have these qualifica- tions, one is an engineer, another was a lawyer and is now a judge, and a third is a business man.

So I conclude, you see, that it is not the vast knowledge of the engineer nor the skills and techniques of the pro- fession, useful as these may be, that put him in position to make a uniquely valuable contribution to the art of dealing with complex economic situations, but I believe he can make such a contribution by passing over into the field of economic practice his habitual way of looking at and dealing with problems, which leads him to see clearly what he wants to accomplish, to take into account sys- tematically all the factors and circumstances which will influence results, and then plan so that the objective may be achieved as nearly as possible by the time wanted and under existing conditions.

It is interesting to consider how the engineering profes- sion might make this contribution. Individual engineers can emphasize the engineering method in their own dis- cussion of economic subjects and urge it in connection

(*Concluded on page 215*)

Industrial and Cultural Japan

By DUGALD C. JACKSON
PAST-PRESIDENT, AIEE

Education and industrial development in the Japanese Empire are here described as seen by the author during his visits to that country, in which he recently delivered a series of lectures under the Iwadare Foundation.

JAPAN and its industries present a picture of interest and significance from many angles. The facts and opinions outlined in this paper were secured in 2 visits to Japan 6 years apart and each of some weeks' duration, a considerable part of the time of each visit having been spent in observing as a matter of personal interest the education and the industry in that engaging country.

Characteristics of the Japanese People

The population of the Japanese empire is now counted as about 95,000,000 people. These are included in the islands of Japan proper and in Chosen (Korea), which is a peninsula of the Asiatic mainland, the island of Taiwan (Formosa), and a few small islands. It is a notably literate population, vying with the United States in the percentage of literacy. The Japanese people are full of sentiment for their ideals in art and literature, for their interpretation of heroes and heroism, and for the beauties of nature as exhibited in Japan; but they also are realists—shrewd and practical.

Americans generally have heard much of the sentimentalism of the Japanese people and have heard little of the other side of their nature and habits. The exaggerated sentimentality of Pierre Loti's writings and the sympathetic interpretation of Lafcadio Hearn have influenced American thought on one side only, and we have not secured a balanced view of this people. There is a degree of reason in this. Even the British poet laureate, Masefield, mystically traces in glamorous words the lure of the broad Orient in his poem describing the stores of the Eastern Merchants:

"We have been told that in the East are things
Flame-guarded by the Phoenix' burning wings,
The Sunstones of the Everlasting Kings;

"The Moonstones from the Woman of the Sea,
The Changestones that compel Eternity
To that which *is*, but yet can never be.

* * * * *

"And silks, that the worm spins and man refines,
Silk of the East with sunlight in its lines
That, at each turn, with other color shines."

* * * * *

In the light of such delightful legends it was easy for Americans to fall under the spell proclaimed by the sentimentalists. It was also easy for a pragmatic people to miss the truth on the other side. We did so in distress over an embarrassing influx into California of low-class coolies, a third of a century ago, and we assumed a patronizing attitude toward the Japanese because some of our citizens (in contact with an inferior class) confused that class with the entire race and dubbed the race inferior.

The recent strong place in the world of affairs that has been assumed by the Japanese nation emphasizes the importance of a fuller examination of the facts and a better understanding by Americans of the Japanese people, their ambitions and their ideals.

In their original feudal stage the Japanese authorities seem to have had neither desire for, nor strong antipathy toward, contact with foreigners. However, clashes with western traders and western proselytizers, who refused to yield to feudal regulations, led to exclusion of foreigners from Japanese soil and the prohibition of almost all trading contacts or privileges. Lasting several hundred years (during which the expostulations of western nations were rebuffed), this state of affairs was disturbed by Commodore Perry of the United States Navy who, in 1853, on behalf of our Government, made approaches to the Japanese authorities for the purpose of establishing mutual relations of friendly nature between the 2 nations and their citizens. Contact having been made, he then temporarily withdrew.

Commodore Perry returned to Japan in 1854, and this time succeeded in opening restricted diplomatic and commercial relations for the United States. European nations joined with America in this opening of Japan anew to foreign intercourse. Our earliest official commercial agent, Townsend Harris, was fortunate in his qualities of forbearance in a somewhat hostile setting, tolerance toward (to him) strange religious beliefs, and competence of imagination for picturing the points of view of alien peoples. The European nations were not so free from the arrogance that arose from an assumed superiority of intellectual level. Neither have we Americans been at all times free from arrogance since the days of Commodore Perry and Townsend Harris, but Harris has stood (in the imagination of the Japanese people) as a representative of the friendly qualities of the American people. We likewise have touched the hearts of the Japanese at other times and by other means, of which a notable example arose through the noble manner, as well as the magnitude

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DUGALD C. JACKSON is professor emeritus and honorary lecturer at Massachusetts Institute of Technology, Cambridge. He was president of the Institute 1910–11. In 1929 he visited Japan as a delegate to the World Engineering Conference in Tokyo; in the latter part of 1935 he served as lecturer at the invitation of the Institute of Electrical Engineers of Japan under the Iwadare Foundation.

our aid to Japan on the occasion of that cataclysmic kohama-Tokyo earthquake and conflagration of 1923, ich destroyed over 100,000 lives and rendered $1^3/_4$ lions of people homeless. The cost to Japan of re-istruction which followed that disaster is estimated at re than 5 billion yen.

Through such relations the informed Japanese feel a ·p sense of gratitude toward the United States and its ople. But this is offset by the sense of resentment ich rests on the whole Japanese population, for what y consider our not infrequently patronizing attitude vard them due to racial differences.

Now the Japanese nation has come to vie with the stern nations in diplomacy, industry, education, and ernational commerce. They started on their career in se fields short of 70 years ago. Their progress in ustrial affairs during the 70 years, while in competition h the most active industrial developments of the stern world, proves them to be a people of intellectual ver rivaling the intellectual powers of their western npetitors, as was foreseen by Theodore Roosevelt in)6. We of the United States are their most important tomers in international trade. They are high in er of importance among our customers. Our greatest nmercial importation from them is raw silk. Their chases from us include much cotton, but (although they e become great industrialists themselves) also include isiderable machinery and other products of manufacture.

panese Education

t is time for the American people to awaken to the t that the Japanese are a highly educated people sessing intellectual powers rivaling our own and entive genius in government and industry which has ome matured and capable by experience. Japan is a ion with which (as in the case of other strong nations) are having and will continue to have commercial alries and causes of friction demanding tactful adjust-nt; but it is a nation which cannot afford serious erences with us, nor can such differences become acute hout loss to ourselves.

'or satisfactory ac-intance between the ples of 2 nations it is irable that each of the ples shall know some-ig of the educational cesses carried on in the ier nation. Only ough such knowledge truly friendly relation-s grow up and be ntained; and only ough such knowledge misconceptions arising n false diplomacy or rs of commercial proc-s be avoided, or (if irring) can be pre-vented from becoming causes of friction. If one knows the processes of education of a people, one may, in a sense, claim to know the characteristics of that people. The writer's observations in his 2 visits to Japan, 6 years apart, each of some weeks' duration, as already said, added to a long life spent in American industry and engineering education, indicate a definite lack of under-standing among the Americans and the Japanese people regarding the processes of education in the other nation. In each nation there are but few individual exceptions to this lack. It is also notably true that the Americans lack understanding of the Japanese civilization and that the Japanese (except for a relatively few individuals among the whole) equally lack a conception of the Ameri-can land or the lives of its people. Space available gives but little opportunity to deal with these features, but the importance of the matter justifies as full an outline as practicable.

In 1868 the Japanese Emperor Meiji shook off the con-trol of the Shogun and took full administrative control in the nation. Feudalism was overthrown. The Meiji Emperor was a man of force and character with a will for the betterment of his people. With the advice and aid of commissions of able Japanese statesmen sent to Europe and America to gather data and formulate recommendations, a parliamentary government was formed, financial and commercial processes were outlined, and education for the masses was established.

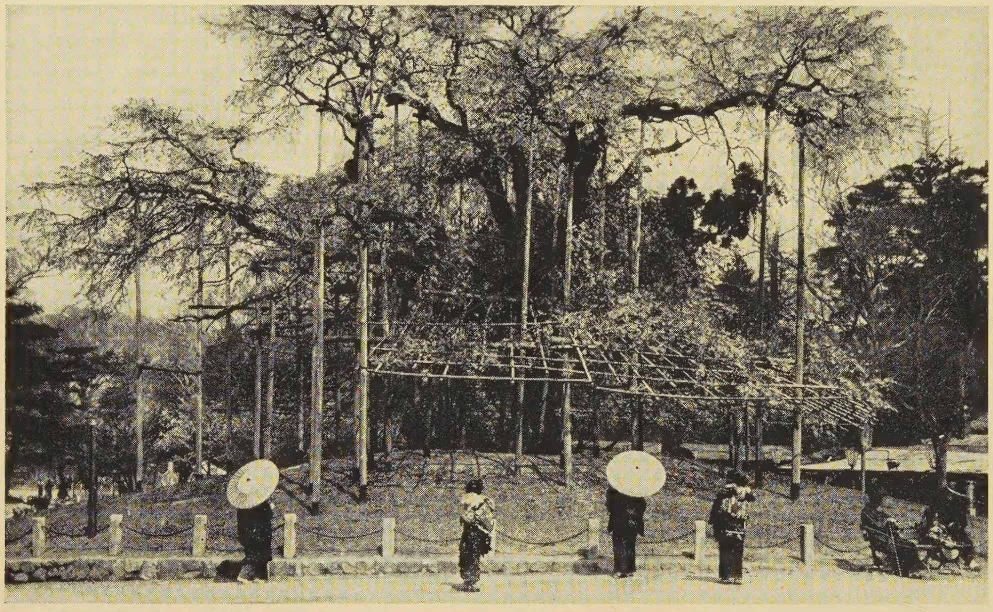
By 1872 a unified plan for elementary, intermediate, and higher education was outlined for Japan, following rather clearly the French standards in the elementary and intermediate processes. By 1880, attendance at school by children up to certain ages was made compul-sory. These educational processes established under the Meiji Emperor have reasonably well fulfilled the expecta-tion for old Japan which is set forth in the Imperial Proclamation, which reads: "Henceforward education shall be so devised that there shall be no ignorant family in the land and no family with an ignorant member."

The elementary educational processes have been modi-fied from time to time since the early establishment of general education, and various later doctrines which have served well in Europe and America have been introduced, besides modifications which seem best suited to the national requirements of the Jap-anese people. In no land is the welfare of the school children more cherished than in Japan, and solici-tous attention is given to their physical welfare as well as their intellectual welfare. As an evidence of the results of care for the physical welfare, sta-tistics are given which

Edison memorial at Yawata, site of original source of bamboo for incandescent-lamp filaments; Professor Jackson is in the center of the group

show that the stature of the children is increasing in height compared with earlier groups. The children also are taken on visits to beauty centers (which are so numerous in Japan), to notable temples and shrines, to museums of art, and to centers of creative thought.

It is now characteristic of the schools that the children work at desks, sitting on benches, instead of following the old Japanese custom of sitting on the floor with little tables before them. The children are usually in uniform dress, which is determined by government, those for the boys corresponding to trousers and jacket suits such as we often see in the west, and for the girls, to skirt and blouse suits, such as we also see in the west. These garments are much more convenient for wear during active exercise or when sitting at the desks than the old-time kimono garments, although the latter are commonly worn at home on account of their relative comfort.



Ancient flowering cherry tree in Kyoto, said to be 400 years old

The elementary education covers a period of a half-dozen years or more. The instruction is done in the Japanese language and no foreign language is taught in most of the elementary schools. The children follow educational processes that are not particularly different from those of the western world but much more attention is given to bringing the pupils in contact with the national ideals than we usually find in the western schools. Indeed, the attention which is given to the health of the children and the supervision of their athletic exercises match our best efforts; and the children's organized visits to seats of great national reputation and natural beauty, and to important shrines and temples, excel the corresponding procedures which we find in the west.

Through these processes, the children grow up in Japan with a wonderful appreciation of the beauties and the symmetries of nature and art in their country, besides being educated in the usual fashion that we associate with literacy. The selection of school teachers is made under rigorous requirements relating to preparation for the teaching work.

Secondary education is carried on equally scrupulously in Japan, although a much smaller percentage of the children transfer from the elementary education into the secondary education than we now find in America. That is, the compulsory education in Japan only applies (for most part) to the elementary portion and the age at which children are released from the compulsion is several years younger than it is in certain of our states. In thinking of these things, however, we must remember that the statutes of Japan apply to the whole nation, with the exception of special provisions made for Chosen and Taiwan, while in the United States we have requirements of different scope in the different states.

For the secondary education, one finds schools of general education (usually referred to as middle schools) and also vocational schools all of excellent grade. In these schools a foreign language is included, which is usually English, French, or German. Since the emphasis is on English, it is possible for an English-speaking visitor to Japan to find a considerable competency in English among the Japanese, and it is almost always easy to find an interpreter. The structure of the Japanese language is so markedly different from English or any other of the western languages that the usual visitor from the west is not quickly tempted to try to learn something of the native language, as he is when visiting in western countries which are neighboring on his own.

Among the vocational schools there are very adequate groups which deal with the particular problems of agriculture, industry, and commerce.

The university program of Japan now is quite extensive. There are in old Japan 6 Imperial universities, and one each in Chosen and Taiwan. These universities, supported by the government, are all of fine order. They are reinforced by many other universities, higher scientific schools, higher commercial schools, research institutes and other higher institutions which have not yet reached (or are not intended for) the scope required for designation as Imperial universities, which designation is conferred under statute by the Ministry of Education. Some of the institutions other than Imperial universities are the result of private endowments, but many are sup

rted by government funds in a manner similar to the pport of Imperial universities. Some are sustained for nited purposes, such as education and research in the lds of medicine, engineering, agriculture, or other fields special import, or as institutes of research in particular anches of science. Important research in fields of ience, with emphasis on applied science, is also fruitlly supported by government ministries and by private dustrial organizations. An official organization, which somewhat analogous to our National Research Council, supported by the government.

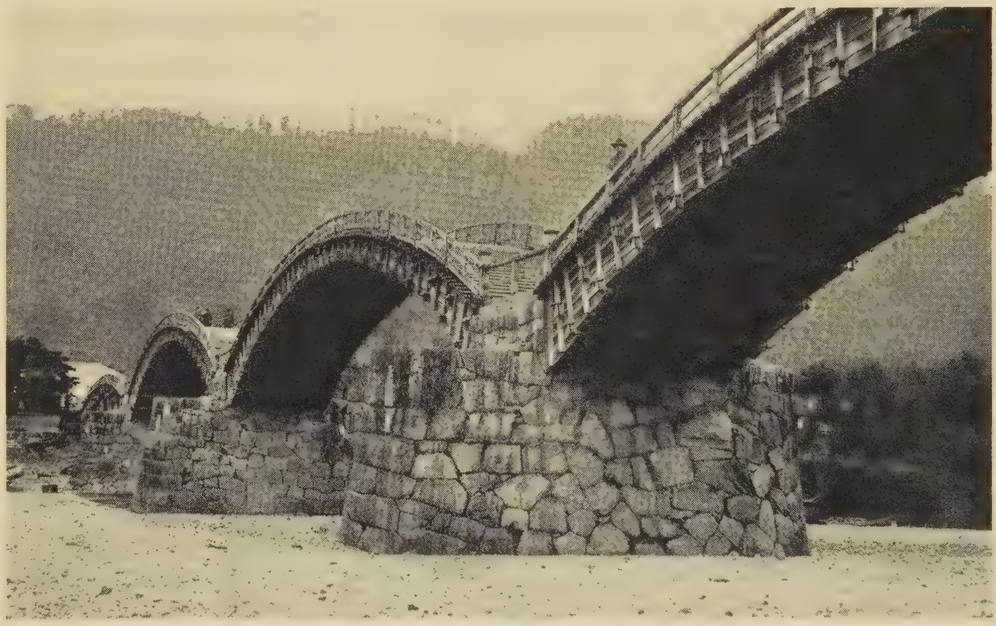
While schooling is compulsory through adolescence, e admissions to Imperial universities and other government-supported institutions of higher education and search are usually by competitive examination accomnied by rigorous limitation in the numbers of students cepted. Consequently the numbers of students in the iversities and higher professional schools are apparently ss, proportionally, than we have in America. This ems notably true of the engineering classes, medical asses, and classes of students in other professional anches; but the standards of work in these branches e established on an admirably high level. For interediate work in these anches there are available certain proportion of polychnic schools, commercial hools, schools of practical riculture, and such like.

Education in science is cognized by the Japanese vernment and people to be feature of great importance ring the expansion of the panese industries which w is going on. A country ming in the last part of e nineteenth century, as a vice, to develop a western pe of education in science d an active participation industrial production, appropriately may give first couragement to rigorous ucation and research in proved applications of ience, and rely at first on e already established nans for the production of ndamental, new, discoveries which to build further. is is especially true where ready money is not easily rthcoming for budgets. The wisdom of the Japanese led em originally to that practice, but they are now establhed in full appreciation of the advantages to themselves supporting a suitable part of the world's work of rearch in the fundamental aspects of science. They do e latter without lessening their attention to further eative work in the useful applications of science or sening their enthusiasm for art and literature.

Japanese Industrial Development

Japan is deeply affected by the electric forces set up by industrialization, which draw people into increasingly populous urban areas. Tokyo, the national capital, is associated with Yokohama and 2 intervening smaller industrial municipalities to make an industrial area of continuous urban population, which is the third largest continuous urban population in the world, being exceeded only by New York and London. This is Japan's greatest center of commerce, finance, industry, and dipolmacy. The seat of the Imperial government (with its imperial residence, its ministries, and parliament house) is located in Tokyo. The area is one of great intellectual and commercial activity.

Osaka is another center of great industrial and business activity, like Chicago, with several million inhabitants. Nagoya is still another large and important industrial municipality. In addition, industrial activity is widely spread over the home islands of Japan. The continuing repute that the Japanese are solely copyists and cannot become creative industrialists is belied by the factories scattered through a wide area in which are manufactured a variety of originally designed products, often made on Japanese machine tools, Japanese looms, and other Japanese machinery.



A very old Japanese bridge of wood, bronze, and iron, reputed to have been built in 1673

The Japanese build their own ships and now bid for ship construction for other nations. They build their own railroad motive-power and rolling stock. They design and manufacture their own electrical machinery. They are beginning the manufacture of automobiles. They manufacture their own steel, although most of the

A panoramic view of the Inawashira power development, one of those which provide hydroelectric power to the Tokyo Electric Company

n ore and much coal must be imported. They are pidly developing in the field of chemical manufacture. ey are notable in the manufacture of textile goods and amic goods. And so on it runs through a wide range manufactured commodities and specialties. The panese are pressing for an increased export trade. ey are keen competitors, and we must be sagacious as ll as alert in protecting our trade situation, even in r home markets, if we are to succeed in doing so without ious friction.

The Japanese were copyists (indeed, they were assiduous pyists) in the early days of their era of industrialization, we also were copyists when we were young in indus-alization, and the Germans were copyists (often to the stress of American makers of machine tools and other chines) in the early ys of their industrial-tion. Like these other tions, the Japanese have come competent to nd, industrially, on eir own feet although the tion woefully lacks pos-ssion of sources of many eded raw materials.

A view in reconstructed Tokyo, showing the Sumida River

It is difficult for nericans, living in a ntinental country pos-ssing sources of raw ma-ials for almost the mut of our needs, to preciate the gravity of e situation for an insular tion which lacks in sential supplies, and to ther appreciate the essure for expansion which that situation imposes. In t, it is even difficult for citizens of Great Britain, a tion that has met such a situation by the development a surpassingly great sea-borne commerce, to view mpathetically the efforts of a growing industrial nation seeking to assure its position by gaining a like status.

The Japanese have demonstrated their ambition and eir ability, and we must face the fact that they are mpetent, and also insistent, as competitors for world ide in manufactured products. They came late into s trade as competitors, but they entered it seriously d with the intent to stay. For illustration, with one ception of a wooden ship, no ship of more than 1,000 ns had ever been built in Japan before 1895. Now at st 4 of their competent group of shipyards and navy rds have built ships up to 30,000 tons.

The Japanese are industrious workers and very thrifty. the agricultural areas, the farm families live from the oduce of tiny (in our ideas) farms of from 1 to 3 acres, ich they intensively cultivate in every available square t. Earnings of daughters and sons who have gone o industrial employment bring some ready money to pockets of farmers, and (to the farmers) the profitable port of manufactured products seems a life line. In their opinion, this life line must be maintained and the nation must be strong in military power and in shipping in order that the life line shall be maintained. The farmers' families work long hours over their crops, but the hours of industrial workers are limited by law to weekly hours that compare on all-fours with those in American factories.

Japan is not a nation of great *per capita* wealth. It is difficult to secure reliable estimates of such wealth, but the Japanese government has published certain estimates which, converted into dollars on the present basis of exchange, make a sorry comparison with our estimated *per capita* wealth. However, such a comparison is super-ficial and inconclusive. A yen (Japan's principal money unit) buys in Japan about as much food, shelter, and clothing of the character demanded by Japanese as a dollar buys in this country to meet our needs, and on this basis of com-parison for the yen Japan possesses *per capita* wealth which is in keeping with that available in several of the important European countries. Although the ratio with our status, even on this basis, may still be low, the Japanese possess a fair amount of working capital, and the develop-ment of further capital is progressing with consider-able speed.

The exigencies of mili-tary expansion are absorb-ing a great deal of money for nonproductive uses, and the public debt is expanding. When doubt is expressed of the wisdom of this policy, attention is politely directed to the extraordinary magnitude of our "New Deal" expendi-tures. Pertinent as is this retort, there nevertheless is a difference which weakens the analogy. Of the total present Japanese funded debt, public and private, per-haps one-quarter as much has been borrowed abroad as at home and the debt service siphons a good deal of wealth away from the country. Establishing textile mills and other industrial establishments abroad, as the Japanese have done in China, also draws wealth from its native land, and diverts wages from homeland wage earners. Increased profits accruing to the homeland may not offset these disadvantages in the case of a country which is without excess of wealth, but the Japanese have proved to be astute in commerce and finance and their wisdom may enable them to avoid undue difficulty from the situa-tion.

Present Status of Japanese Industry

The World War had a great influence on Japanese industry, and nations meeting Japan in lively competition

A scene in Tokyo illustrating the charm of Japanese architecture

for world's trade in manufactured products can lay much of Japan's present industrial stature to the impulse arising out of the demands of that war. Up to 1914 the industrial situation in Japan had been for a decade or more in a state of expansion at a moderate rate, but during the World War, Japanese industries embraced the opportunity for very rapidly expanding their world trade, and industrial production bounded upward accompanied by rapid expansion of plant and enlargement of the number of industrial employees. The principles of mass production, guided by scientific management, were adopted in many localities. Manufacture of iron and steel, electrical machinery, machine tools, textile goods, ceramic goods, chemical goods, matches, portland cement, paper, and other commodities were all pressed forward, as also was the preparation of foodstuffs.

The homeland (that is old Japan, which consists of the islands of Honshū, Kyushū, Shikoku, Hokkaidō, and accessory islands), possesses some 48,000 kilometers of coast line, indented with some 1,900 harbors, of which 153 are important. The great industrial cities are located on these harbors, and deep water is directly alongside many factories. A great deal of local transportation of goods is therefore by water, and shipping is of large importance. Bounties for ship building and subsidies for ship operation have been part of government policy.

Electric power, generated both by fuel and water, has been largely developed, and power transmitted at 154 kv serves the larger centers. It is estimated that $6^3/_4$ million horsepower in firm power and $13^1/_2$ million horsepower in 6-months' power may be secured from water power when the potential hydroelectric plants are all developed. As coal is of reasonable price, much fuel-generated power is associated with the water power. If any reader desires more specific information regarding the Japanese electrical industries, he may refer to my very brief article relating to them which w published in *Electrical Wor* July 18, 1936. It is said th seven-eighths of the houses the homeland use electricit but the domestic use of kilowat hours is actually small becau of the few lamps installed most houses and the low wat age of those installed, a modest incomes preclude t general purchase of electr household appliances.

Mining is a very old art Japan, and a long list of mi erals are mined; but, of t more important mineral ores a commodities, the supply fro Japanese soil is insufficient f present industrial demands a importation has to be resort to. Nevertheless, Japan no is producing most of its ov requirements in iron and ste using mostly imported iron ore and some imported coa

Industrial wages of Japan are small (when convert to American money at the rates of international exchang compared with wages in this country, but (as previous pointed out) this makes an inconclusive compariso In comparison with cost of food, clothing, and shelter the 2 countries, the Japanese working people are as we paid as our working people were some decades ago, a in the many plants, of many varieties of productio which I have visited, the working people look health well fed, contented, and interested in their work. O manufacturers who feel the pinch of Japanese competitic must come to understand that the Japanese accomplis ments are not secured by oppression or exploitation of t working people. Acumen and good management, ass ciated with an as yet relatively very low cost of livin make the combination that has brought the Japane competition to success. Aid to export business given the government has also contributed its advantages to t Japanese exporters.

As to the manufacturing processes of the Japanes they are good. They have been greatly improved duri the past half-dozen years. Accuracy in mass productic is secured in the factories. Committees participate

A Japanese private garden at Kyoto

ternational standards conferences and set standards of onstruction and manufacture for Japan. Refined testing achines, measuring instruments, and other instruments f precision of Japanese manufacture are now generally vailable. Research laboratories, working devotedly on e problems within their respective fields, are a general eature of the industries, the government ministries, and epartments of universities.

As household industries were developed in feudal times nd have continued to the present time, many items of dustry are still produced in this informal manner. uch products are likely to be of variable quality, or of w grade, and the government is reported to have plans r putting all such products through tests and inspecion in case the products are intended for exportation. his has already been done, for perhaps a dozen years, r raw silk, and may now be in practice for other comodities.

thics and Religion of the Japanese

Shintoism and Buddhism are the religions most influntial in Japan, but Shintoism is easily the first in influnce, being bound up with the cult of the 3 sacred objects the sword, the jewel, and the mirror), and the divine aternity of the Emperor. The Japanese are fundaentalists on the divine descent of the Emperor, and heir ethics are bound up with that tenet. This gives an spect to Japanese ethics which is not found in the ethics ecognized in western nations, or recognized among the hinese whose ethics came down through the illuminating terpretation of Confucius.

Perhaps part of the friction between the Americans nd the Japanese arises from this component of ethics hich lacks mutuality. We compose 2 peoples with resent-day cultural ideals somewhat alike, with ethics milar in the main, but with one deeply modifying aspect hich pertains to the beliefs of the people of one of the ations. The highest ideal of a Japanese citizen is sinerely bound up in loyalty to the Emperor and the welfare f the nation. The honor of the Japanese individual lies ere first. Man-to-man relations and commercial relaons trail after, as a matter of fundamental religion.

The western world has been in diplomatic and comercial relations with Japan and the Japanese for only bout three-quarters of a century. This is a short time ithin which to secure mutual understanding between 2 lf-reliant and ambitious peoples who live in such diverse tuations and are of such diverse antecedents. Suddenly stablished extreme and continuous intimacy requires me for making adjustments before understanding is stablished and frictions are overcome. This situation f sudden intimacy has been imposed on the relations of e peoples of the United States and Japan by the intiacies due to steam-power transportation and new modes f quick communication. Sufficient time has not yet apsed for the roughnesses of contact to be smoothed and ftened by experience and adjustment.

Can the causes of friction between our 2 nations be adicated?

In the realm of science, a theory is a statement which is equivalent to the explanation of any relationships which have been discovered to exist between measured apparent facts. This serves as a guide in seeking out additional relationships. The situation in international affairs, unhappily, is too complex for fitting a theory to guide the adjustment of relationships. In the example of these 2 great nations, our differences can only be adjusted by continued mutual observation, self-restraint, tolerance, and good sense, which lead to mutual respect and appreciation.

Engineers and Economics

(*Continued from page 207*)

with discussion by others. But the situation is so vast and complicated and has so many divisions which interact on each other that it seems to be beyond individual effort and to call for the kind of mass attack which our great industries use in their research and engineering departments for dealing with their physical problems. The telephone industry furnishes outstanding illustration of what I mean. Theodore Vail, and the able men who succeeded him, appear to have set for themselves the ideal goal of producing communication machinery through which anyone anywhere in the world may talk to anyone anywhere else, and they have gone an amazing distance toward the realization of that goal. That has involved dealing with a vast complexity of subjects which range from elementary engineering to advanced and difficult mathematics and physics. How far would the art have progressed by now if the leaders of the industry had contented themselves with development by the tedious and uncertain processes by which we have been satisfied for the most part and until recently, to allow our knowledge of economics to translate itself into working plans? They organized for the attack on their problem great research and engineering establishments, staffed them with the ablest men they could command, and backed them financially on a magnificent scale.

A few similar organizations for mass attack on the economic problem are already in existence. The National Bureau of Economic Research and the Brookings Institution, already referred to, are 2 outstanding illustrations. Others, such as the Falk Foundation, The Twentieth Century Fund, and the National Industrial Conference Board, might be mentioned. In varying degrees numerous other organizations deal with limited areas of applied economics. Graduate schools of business administration, management societies, trade associations, etc., are in this class. It is a common experience of engineers, as they rise in their profession, to find themselves drawn more and more into management and administration, and through these interests into association with organizations of the kinds just mentioned. Here they have an opportunity to carry the engineering approach into a field where it is much needed, and to help build on the basis of economic theory and knowledge a socially useful art of economics.

Unemployment in the Engineering Profession

Reporting further upon the results of the 1935 survey of the engineering profession conducted by the United States Bureau of Labor Statistics, at the request and with the co-operation of American Engineering Council, this article* presents the Bureau's analysis of the unemployment data obtained.

AS FAR as is known, the recent depression was unique in its disastrous repercussions upon professional groups. Unemployment has for decades been recognized as a major form of insecurity affecting wage earners, and fairly reliable data concerning this have been made available from time to time. Precise knowledge as to the extent of the depression's impact upon professional workers, however, has been lacking.

As a result of a survey of the engineering profession undertaken in May 1935 by the United States Bureau of Labor Statistics, at the request of American Engineering Council, it may now be said that at the end of 1932 more than $^{1}/_{10}$ of the engineers were simultaneously unemployed, that at one time or another between the beginning of 1930 and the end of 1934 more than $^{1}/_{3}$ of the engineers had some period of unemployment, and that half of those who became unemployed were out of work for more than a year. Unfortunately, there are no comparable data for the other professions.

From the 52,589 reports from professional engineers throughout the country, the following summary analysis of unemployment, including work relief and direct relief, may be presented:

1. Between the end of 1929 and 1932, the percentage of engineers who were unemployed increased from 0.7 to 10.9. At the end of 1934 the percentage was 8.9.

2. At no time was direct relief extensive among engineers, but the development of work-relief programs after 1932 became an important factor. Although 10.9 per cent of all engineers reporting were unemployed on December 31, 1932, less than $^{1}/_{15}$ of those unemployed were on work relief. On December 31, 1934, 4.0 per cent of all engineers reporting had work relief, that is, almost half the total number of engineers unemployed at that time.

3. The largest number unemployed at any one time was about 11 per cent of the total, but more than a third of the engineers had some period of unemployment within the 5 years, 1930–34.

4. Among those who became unemployed at some time during these 5 years, half were out of employment (except as they found work relief) for more than a year.

5. This experience with unemployment was common to all professional classes of engineers. In 1932 unemployment ranged from 10.1 per cent among chemical and ceramic engineers to 11.6 per cent among electrical engineers. In 1934 approximately 8 per cent of the electrical, mechanical, and industrial and of the mining and metallurgical engineers were unemployed. The percentage of unemployment dropped most among chemical engineers, of whom 6.8 per cent were unemployed in December 1934. There was a slight increase in unemployment among civil engineers from 1932 to 1934.

6. The most marked differences as regards unemployment are those found among the various age groups. The greatest frequency of unemployment was among those who attempted to enter the profession after 1929. Approximately half of them were unemployed at one time or another from 1930 to 1934. Older engineers, who were already professionally established prior to 1929, were less frequently unemployed, though even among those with 20 or more years of experience $^{1}/_{4}$ had so unemployment.

7. When the older engineers came unemployed, however, u employment lasted longer than did with the younger enginee Thus, the median period of une ployment for engineers graduati in 1925–29 was 12.1 months, whe as the median for those graduati prior to 1905 was 23.1 months.

8. The effect of this longer period of unemployment among old engineers was cumulatively to produce a higher percentage of u employment among older engineers than among younger enginee Thus, in December 1934, 11.5 per cent of the engineers 53 years age or more were unemployed, in contrast to an average of 7.3 p cent of the younger engineers who were exposed for the same peri to the risk of possible unemployment.

9. The type of education the professional engineer had receiv did effect variations on both the incidence and severity of uner ployment. These factors were very much less for postgraduat than for engineers with other types of education. But as betwe engineers with first degrees in engineering and those whose colle course was incomplete or who had attended noncollegiate technic schools, the differentials were very slight.

10. The influence of regional location on unemployment was pra tically negligible, whether considered from the point of view differentials in incidence or of severity of unemployment.

The sources of these data are the replies received to questionnaire mailed to 173,151 engineers. One questic called for employment status on each of 3 dates, thu giving a cross section as to employment, unemploymen work relief, and direct relief on December 31, 1929, 193 and 1934. From these reports the general trends unemployment have been traced. A second questio related to the number of months of unemployment ove the 60-month period January 1, 1930, to December 3 1934. Consequently, it is possible to measure the inc dence and severity of unemployment, work relief, an direct relief for 5 years of the depression, as well as a other dates.

In keeping with the other analyses of this surve these subjects, wherever warranted, are so presented a to determine their significance when related to (1) typ of education, (2) professional class, (3) age, and (4) region location.

Unemployment at End of 1929, 1932, and 1934

The first part of the discussion will be concerned wit trends in unemployment. For the country as a whol

* Essential substance of an article prepared by A. F. Hinrichs, chief economis and Andrew Fraser, Jr., of the Division of Wages, Hours, and Working Cond tions, Bureau of Labor Statistics, United States Department of Labor, whic article was published in the January issue of the *Monthly Labor Review*. Th is the second of a series of summary articles covering the results of this surve The first article dealt with the educational qualifications of the engineer, an was published in the *Monthly Labor Review* for June 1936 (page 1528); als reprinted as Bureau of Labor Statistics Serial No. *R* 400. The essential su stance of the first article was published in the August 1936 issue of ELECTRICA ENGINEERING, pages 863–7. A detailed report of the survey will be publishe later in bulletin form by the Bureau of Labor Statistics.

e was an appreciable decrease in unemployment ng professional engineers between December 31, 2, and December 31, 1934. Thus, while the propor- unemployed on December 31 rose from 0.7 per cent 929 to 10.9 per cent in 1932, it had declined to 8.9 cent by 1934 (table I).

he decreases in unemployment among engineers from 2 to 1934 must not be thought to imply an increase in proportion engaged in engineering employments. le a larger proportion[1] of the engineers were employed 934 than in 1932, the gain, if all professional classes considered in combination, occurred in nonengineering k. Increases of nonengineering employment were icularly important to electrical engineers. Only in case of mining and metallurgical engineers was there rge increase in the percentage reporting engineering loyment.

he most striking fact in table I is the narrow range he proportions of unemployment among the various essional groups for each of the 3 periods. This is cially true for 1932 with a range of from 10.1 per

e I—Per Cent of Engineers of Each Professional Class Unemployed* on December 31, 1929, 1932, and 1934, by Type of Education

	Per Cent Unemployed on Dec. 31—														
	1929					1932					1934				
		Others with—					Others with—					Others with—			
Professional Class ‡	All Types of Education	Postgraduates	First Degree Graduates	College Course Incomplete	Noncollegiate Technical Course	All Types of Education	Postgraduates	First Degree Graduates	College Course Incomplete	Noncollegiate Technical Course	All Types of Education	Postgraduates	First Degree Graduates	College Course Incomplete	Noncollegiate Technical Course
gineers	0.7	0.5	0.7	0.9	1.1	10.9	8.1	11.5	10.4	11.1	8.9	6.3	9.1	10.3	10.0
ical and ceramic	0.5		0.4	1.6		10.1	6.5	11.3	7.9†	25.0†	6.8	3.2	7.7	5.8†	23.8†
agricultural, and architectural	0.7	0.5	0.7	0.8	1.4	10.5	9.4	10.8	10.2	11.7	10.8	9.6	10.9	11.9	13.3
rical	0.8	0.8	0.3	0.6	1.4	11.6	8.5	12.5	9.6	10.3	8.0	5.7	8.2	9.3	8.6
anical and industrial	0.7	0.5	0.8	0.9	0.4	11.3	6.4	11.8	11.9	10.5	7.5	4.5	7.9	8.2	6.3
ng and metallurgical	2.1	0.7	2.1	2.1	3.8	10.9	9.3	12.0	8.3	9.6	8.3	7.0	8.8	8.4	11.2

luding those on direct relief and work relief.

ese figures are believed to be without significance.

total numbers of engineers in the various classes reporting unemployment is not shown in this article, but will become available in a statistical appendix to cluded in the complete report to be published by the Bureau of Labor Statistics. While the percentage of unemployment was 1/5 less in 1934 than in 1932, umber of engineers reporting employment in 1934 was 48,124 as against 40,721 in 1932, due to the entrance of new persons into the profession. The number ting unemployment dropped from 4,448 in 1932 to 4,288 in 1934, a decline of less than 4 per cent. Due to the overrepresentation of recent college graduates sample and the high percentage of unemployment among them, the total number reporting unemployment in 1934 should not be compared with the total er reporting unemployment in 1932.

for the chemical and ceramic engineers group to per cent for the electrical engineers.

CATION

he type of education the engineer had received cted the extent of unemployment (table I). Thus, 932 the proportion of all postgraduates who were nployed was only 2/3 that of graduates with a first ree in engineering. Among chemical engineers and hanical engineers, the difference in favor of the post- luates was greatest. The smallest difference occurred ng civil engineers. The same characteristic relation-ships occurred in 1934, although, for all but civil engineers the decrease in unemployment was marked.

There is no clear evidence in table I of a relationship between the extent of unemployment among those engineers whose college work was incomplete, or who attended noncollegiate technical schools, and those who had first degrees.

Age

The outstanding feature of table II is that a larger proportion of the older engineers remained unemployed on December 31, 1934, than was true of those graduating from 1905 to 1932. Further inspection of table II shows very clearly that by December 1934 many of the older engineers were still unable to obtain work; and there is a very strong presumption that the preference in new hirings was given to the younger man. This is partly explicable on the grounds that, first, the older engineers probably were in a better position financially to weather the continuing depression, and second, that the available professional employment opportunities were of such a nature as not to be in keeping with their experience or their customary salary status.

In summary, this analysis of trends shows that: (1) there was a distinct improvement in the unemployment status of professional engineers between December 31, 1932, and December 31, 1934; (2) there were but slight differences in the incidence of unemployment among the various professional classes in 1932 and, except for civil engineers in 1934; (3) engineers who had received postgraduate degrees fared better than engineers with other types of training; and (4) as between older and younger engineers, the former not only felt the effect of the drop in business activity earlier than the latter but unquestionably were still lagging, at least until December 31,

should be emphasized that increases and decreases referred to are with nce to a shifting total sample. See footnote to table I.

1934, in the return to professional activity. In general, it may be said that in this period of contraction of business activity, the inexperienced newcomer had greater difficulty in securing a professional status than any other class, that those with 5 to 25 years' experience fared best as regards unemployment, and that there was little difference (except for chemical engineers) in the percentages of unemployment at a given date between those with less than 5 years' experience and those with more than 25 years' experience.

In a period of expansion the younger and the more inexperienced engineers have a definite advantage. The normal method of recruitment at the bottom is followed. It is to be noted from table II that by December 31, 1934, the percentage of unemployment in all professional classes showed little variation between the age groups that entered the profession as late as 1932 and those with an upper limit of 53 years of age. However, there is evidence that in the 4 largest professional classes unemployment continued to be relatively high among the group of engineers who were more than 53 years of age in 1934.

Incidence and Duration of Unemployment Among Professional Engineers, 1930–34

The preceding discussion presented unemployment data as of given dates, but gave no measure either of the number who were unemployed at other times during the 5-year period or of the length of unemployment. Light is shed on these points by the data obtained as to the period of unemployment, that is, the number of months during which the engineers were on work relief[2] or were without work of any kind. The data in this section therefore afford a measure of the gross or over-all period of displacement from regular employment, without regard to the mitigating effects of various types of relief.

More than 35 per cent of all the engineers reporting were unemployed at one time or another within these 5 years, as against about 11 per cent who were unemployed on December 31, 1932. The percentage who reported unemployment at some time during the 5 years, January 1, 1930, to December 31, 1934, with a classification by age and type of education, is shown in table III. The slightly lower incidence of unemployment for the "other" engineers is explicable on 2 grounds: (1) As a statistical "freak," arising out of slight differences in the age distribution of graduates and "other" engineers; and (2) the longer experience record of "other" engineers, for the graduate sample is especially heavily weighted by newcomers to the profession during the depression period 1930–34. For each particular age group shown in the table there is a slightly higher percentage of unemployment.

It is evident from table III that unemployment was greatest among the newcomers to the profession and decreased with the age of the engineer. In all professional groups there appeared an age beyond which there was apparently a common risk of unemployment. That age varies among the several professional classes. civil engineers it was 43 years, whereas for electrical, mechanical and industrial engineers it occurs afte years of age.

It may be noted that for the 2 youngest age groups percentages affected by unemployment are practically same for all 3 types of education, with roughly half engineers who entered the profession during the de sion period reporting some period of unemployment.

These findings seem definitely to extend the conclus reached earlier as regards the influence of educati background. Table I showed less unemployment 1932 and 1934 among those with post-graduate deg than among those with first degrees, but there wer

Table II—Per Cent of Engineers in Each Professional Unemployed* on December 31, 1929, 1932, and 1 by Age or Year of Graduation†

Approximate Age in 1934 of "other" Engineers	Year of Graduation of Graduate Engineers	Per Cent Unemployed on Dec. 31— All Classes	Chemical and Ceramic	Civil, Agricultural, and Architectural	Electrical	Mechanical and Industrial
1929						
53 and over‡	Prior to 1905	1.9	0.7	1.7	2.2	1.8
43–52	1905–14	0.7	0.5	0.9	0.3	0.6
33–42	1915–24	0.4	0.5	0.4	0.3	0.2
28–32	1925–29	0.4	0.3	0.3	0.4	0.6
25–27	1930–32					
23–24	1933–34					
1932						
53 and over‡	Prior to 1905	10.9	3.9	11.2	10.0	11.3
43–52	1905–14	8.7	7.0	8.8	7.1	9.6
33–42	1915–24	8.0	5.0	8.9	6.6	8.7
28–32	1925–29	10.6	8.8	10.2	9.9	11.9
25–27	1930–32	16.6	15.8	14.7	20.2	15.6
23–24	1933–34					
1934						
53 and over‡	Prior to 1905	11.5	5.9	12.3	11.4	10.2
43–52	1905–14	8.1	4.1	9.0	7.3	7.7
33–42	1915–24	7.0	4.4	8.9	5.5	6.0
28–32	1925–29	7.0	5.5	9.2	5.3	6.0
25–27	1930–32	8.0	4.9	11.5	6.9	5.8
23–24	1933–34	13.9	11.9	18.0	14.6	10.4

* Including those on direct relief and work relief.

† In order to obtain a datum whereby direct comparisons could be made bet engineers with and without degrees, the median age of graduation amon several professional classes was computed. This was found to be 23 Consequently, the data were so tabulated to permit of groupings by ye graduation and corresponding year of birth for each of the periods 1929, and 1934. In this table engineers with college degrees in the years indi are combined with "other" engineers of the ages given in the table.

‡ The criticism has been made that the percentages of unemployment s here relate to the indefinite group of those "53 and over." The figures presumably be smaller if the group were closed at 62 years of age. It is certain from the contour of the percentages both in 1932 and 1934 tha percentage continues to rise with age. It is also certain that the high centages shown are due to the persistence of unemployment when it o rather than to a rising risk of unemployment.

decisive differences between first-degree graduates "other" engineers. It may now be stated that this not due to the age composition of the 2 groups, for w age is considered (table III) the college graduate appear to have an advantage.

For further consideration of the incidence of un ployment by age, the data in table III are shown f distinct groups of engineers, those entering the pr

2. Excluding work on P.W.A. projects and in nonrelief administrative positions in the public service.

n during the depression years 1930–34 and the 4 older ups who had entered the profession prior to 1929. ese 4 older groups had a common experience as regards period during which they were exposed to the risk unemployment. However, the younger engineers e exposed to a shorter period of risk, a factor of great ortance when the length of their employment is sidered. They were also subjected to the necessity making their way into the profession under singularly icult conditions. Length of exposure appears to have n a factor even as regards the general incidence of mployment, for a slightly larger proportion of those o graduated in the period 1930–32 were unemployed ing this 5-year period than was the case for those duating in 1933–34.

For the 4 older groups, all entering the profession before 0, the largest percentage of unemployment occurred ong those who entered slightly before the beginning he depression. There appears to have been no greater dence of unemployment among engineers 53 years age and over than there was among those 43 to 52 rs of age. Therefore, relating this analysis to the ceding discussion of table II, it can only be concluded t the higher percentage of unemployment for the est age groups as of December 31, 1932, and Decem- 31, 1934, is due not to the more frequent occurrence nemployment but to the greater length of the period nemployment when loss of position occurred.

These findings as regards the extent of unemployment ong engineers in general are confirmed by the analysis he separate professional classes of engineers shown in le IV.

Table III—Percentage Distribution, by Age and Type of Education, of All Engineers Reporting a Period of (Gross*) Unemployment, 1930–34

Item	Age (in Years) in 1934	College Graduates: Per Cent Reporting Unemployment
All graduating classes		37.8
Entered profession during 1930–34:		
Graduated in—		
1933–34	23–24	47.1
1930–32	25–27	53.5
Entered profession in 1929 or earlier:		
Graduated in—		
1925–29	28–32	36.0
1915–24	33–42	27.1
1905–14	43–45	23.8
Prior to 1905	53+	23.5

Item	Age (in Years) in 1934	Other Engineers With—College Course Incomplete: Per Cent Reporting Unemployment	Other Engineers With—Non-collegiate Technical Course: Per Cent Reporting Unemployment
All years		35.4	35.6
Entered profession during 1930–34:			
Born in—			
1910–14	20 24	47.9	48.2
1905–09	25–29	49.5	49.8
Entered profession in 1929 or earlier:			
Born in—			
1900–04	30–34	39.0	41.4
1895–99	35–39	33.4	34.1
Prior to 1895	40+	30.4	32.3

* Includes periods both of direct relief and work relief.

This table does not show the percentage of unemployment among engineers with only a secondary-school education, for their number was too small to warrant classification by age. The percentage of unemployment among all such engineers was 22.6.

riods of Unemployment

Gross unemployment" is used in this section to cover iods of work relief or periods without work of any kind. e figures show the median periods of unemployment.[3]

Table V shows the median periods of unemployment, age, education, and professional classes, during the ear period. In connection with the age classifications wn it is important to remember the period of exposure he possibility of unemployment.

There are significant differences in the period of unem- ment as between the various age groups of engineers as between engineers with different types of educa- al background. There are real differences between several classes of engineers, but professional class had ss marked influence on the average period of unem- ment than either age or educational background.

The influence of educational background appears to be sistent whether the data are classified for each of the essional classes or for all engineers combined. How- , the difference of almost 5 months in the median od shown in table V as between all college graduates out regard to age and all those whose college course incomplete exaggerates the spread. It may be that e was no spread in the case of the older engineers; the impossibility of making identical age groupings prevents any other conclusion than that, in the case of older engineers, educational background is no longer a determining factor. Comparison of the median period of unemployment in similar brackets beginning with the engineers who were approximately 30 years of age in 1934 indicates that unemployment lasted only 1 or 2 months longer in the case of those with an incomplete college record. Although in the case of the 2 youngest groups of engineers the college graduate appears to have had some advantage, there is reason to believe that the difference between an average period of 7½ months for the graduates of the classes 1933–34 and 12½ months for those 20 to 24 years of age with an incomplete college record is due in large part to the fact that the latter group had a longer work history and consequently a longer period of exposure. For civil engineers classified on an age basis there was also a persistently longer period of unemployment for those with an incomplete college record.

As between the 2 types of "other" engineers, the difference of 1 month in the average appears to arise from the experience only of the younger engineers. For those over 35 years of age in 1934, there was no difference. In the younger age groups the differences ranged from 1.3 months to 2.5 months, and in all cases, those with an

n other words, the middle point, half the engineers having had a longer l and half a shorter period of unemployment.

Table IV—Percentage Distribution, by Age and Professional Class, of Graduate and College-Incomplete Engineers Reporting a Period of Gross Unemployment,* 1930–34

Graduating Class or Year of Birth	Age (in Years) in 1934	Chemical and Ceramic	Civil, Agricultural, and Architectural	Electrical[a]	Mechanical and Industrial	Mining and Metallurgical
		Per Cent Reporting Unemployment Graduate Engineers				
All graduating classes		33.5	41.8	36.9	35.0	33.9
Entered profession during 1930–34:						
Graduated in—						
1933–34	23–24	40.3	55.1	48.9	40.7	45.6
1930-32	25–27	44.3	59.7	54.7	48.5	54.7
Entered profession in 1929 or earlier:						
Graduated in—						
1925–29	28–32	29.8	41.9	31.3	34.2	33.7
1915–24	33–42		34.4	19.6	25.4	23.9
1905–14	43–52	15.1	26.8	17.2	24.7	
Prior to 1905	53+		27.0	17.1	23.3	
		Engineers With College Course Incomplete				
All ages		†	39.1	†	‡31.2	†
Entered profession during 1930–34:						
Born in—						
1910–14	20–24	†	55.9	†	‡41.8	†
1905–09	25–29	†	57.3	†	‡42.0	†
Entered profession in 1929 or earlier:						
Born in—						
1900–04	30–34	†	43.5	†	‡34.4	†
1895–99	35–39	†	37.8	†	‡29.3	†
Prior to 1895	40+	†	33.3	†	‡26.3	;†

* Includes periods both of direct relief and work relief.
† Included with mechanical and industrial.
‡ Includes chemical and ceramic, electrical, and mining and metallurgical.
a. The high general average for electrical engineers shown in the table is due to an especially high rate among the newcomers to the profession.
It should be noted that in the case of all graduate engineers, it was necessary to make certain combinations of professional classes. Thus, a small number of ceramic engineers were combined with chemical engineers. Civil, agricultural and architectural engineers were combined, but the group was dominated by civil engineers. Mechanical and industrial engineers were combined, as were also mining and metallurgical engineers. In the case of the "other" engineers there were too few cases of noncollegiate technical-school graduates to warrant tabulation of the period of unemployment by both age and professional class; hence, only the data for those whose college course was incomplete are tabulated. This group has been divided to distinguish civil, agricultural, and architectural engineers from mechanical and all other types of engineer. Inasmuch as the unemployment experience of civil engineers differed from that of all other classes, this grouping into 2 categories makes possible general comparisons between the unemployment experience of graduate engineers and those with an incomplete college course. The percentages of these various professional classes of engineer who reported unemployment at some time during the 5-year period, 1930–34, are shown here by the age groupings heretofore shown.

incomplete college course had the shorter period of unemployment.

The average length of the period of unemployment increased with age. Whether the differential for noncollegiate technical-school graduates of these ages is real, or is due to certain peculiarities of the sample, cannot be said; but for all professional classes of engineers there was also a slight increase in the average period of unemployment among those who graduated before 1925 as compared with those who graduated later. By and large, however, those engineers who were 30 to 40 years of age and became unemployed were unemployed for 12 to 14 months, but within these limits age was not an important factor.

It is interesting to note that the engineer who entered the profession during the period 1930–32 had an average period of unemployment almost identical with that for the engineers who had entered just prior to the depression. This was true in spite of the fact that the younger men had a shorter period of exposure to unemployment; their lack of experience obviously militated against their absorption.

In general, it may be said that the average period of unemployment for graduate engineers tended to increase from about 1 year for those who graduated between 1925–29 to almost 2 years for those who graduated prior to 1905. The older engineer suffered from unemployment because of its greater length when it occurred rather than because of its greater frequency. Although the proportion of those who became unemployed over the 5-year period was only $^2/_3$ as great for the oldest group as it was for the youngest group to enter the profession prior to 1930, when unemployment did occur it tended to last twice as long in the case of the older engineer.

Comparison of the severity of unemployment among the professional classes is confined to those 4 age groups that had entered the profession prior to 1930, for averages could not be shown for all age classes of chemical and ceramic engineers, as the number of those over 33 years of age was too small to allow of subdivision. It is apparent, however, that the average period of unemployment was not more than $^2/_3$ as long for chemical and ceramic engineers as for the various other classes. The period of unemployment of mining and metallurgical engineers was probably somewhat shorter in the various age classifications than it was for the 3 larger professional classes.

The general averages indicate comparatively little difference, as regards the period of unemployment, between civil engineers and electrical and mechanical and industrial engineers.

Although unemployment occurred more frequently among civil engineers than in any other engineering class, its severity was slightly less than for the other classes.

The median periods of unemployment cited show clearly enough the differences among the various groups. Long as these average periods were, they still fall short of conveying the full picture. This may be gathered from table VI, which shows the percentage of engineers who reported varying periods of unemployment. It covers only engineers with college degrees received in 1929 or earlier years, without regard to professional class.

Public Relief Among Professional Engineers, 1930–34

In the majority of cases engineers survived without public assistance their periods of unemployment from 1930 to 1934. This was especially true of those who entered the profession prior to 1930.

The first data to be considered are with reference to direct relief. Fewer than 1 per cent of the engineers reported themselves to have been unemployed on December 31, 1929. At that time there were no work-relief projects and none of the engineers reported themselves as on direct relief.[4] Nearly 11 per cent of all engineers reported themselves as unemployed on December 31

932; 31 engineers reported themselves as on direct elief—less than 1/10 of 1 per cent of all the engineers and /2 of 1 per cent of the number reporting unemployment.

For the 5-year period as a whole, receipt of some direct elief was reported by 0.8 per cent of all engineers with ollege degrees and about 2 per cent of those who attended oncollegiate technical schools or who did not complete heir college courses.[5]

Engineer's training was required in the administration f many of the projects designed to benefit other groups n the community. There was also a large increase in onrelief forms of public employment. This was of paricular benefit to civil engineers, of whom 8.5 per cent vere employed by the Federal Government on December 1, 1929, and 18.6 per cent were so employed on December 1, 1934. For civil engineers the increase in this form f employment was greater than the increase in work relief.

Despite the increase in public employment, work-relief rojects were the main source of assistance to those who vere unemployed. On December 31, 1932, when nearly 1 per cent of the engineers were unemployed, only .7 per cent were on work relief. Two years later 4.0 per ent of all engineers were on work relief, which was approximately half of the total number of engineers unemloyed at that time.

The reports for December 31, 1934, show striking lifferences in the extent of work relief as between civil ngineers and other professional groups. At that time .6 per cent of all civil, agricultural, and architectural ngineers were on work relief, as compared with only 2.3 er cent of all the other professional classes combined. The difference probably reflects chiefly the development f work programs that called especially for the civil engiieer's training; it also reflects the fact that the total mount of unemployment among civil engineers in their ormal fields increased from 1932 to 1934, whereas it lecreased in the other professional classes. The greater mount of work relief among civil engineers balanced heir more widespread unemployment. There was comparatively little difference between civil engineers and he other professional groups as regards the net amount f unemployment on December 31, 1934; those entirely vithout work (including work relief) formed 4.2 per cent f the civil engineers as compared with 5.3 per cent of the ther types combined.

Work relief was slightly more common among engineers vithout college degrees than among those who were ollege graduates. The situation with reference to direct elief has already been noted. Among the civil engineers .2 per cent of the college graduates, as against 7.9 per ent of the others, were on work relief on December 31, 934. For the 5 years as a whole, 18.4 per cent of the graduate civil, agricultural, and architectural engineers group reported a work-relief experience, whereas 19.6 per cent of this same group of professional classes with an incomplete college course so reported.

Comparison of the proportions receiving work relief at the close of 1932 and 1934 indicates that the older engineers were favored prior to 1932, while the more recent graduates were being favored in 1934. In 1932 the group graduating in the period 1930–32 had a larger proportion of its membership unemployed than any of the other age classes, but the proportion on work relief (0.6 per cent) was slightly less in December 1932 than the proportion among the older engineers (0.8 per cent of those graduating from 1915–29 and 0.7 per cent of those graduating prior to 1915). Among the civil, agricultural, and architectural engineers the difference in favor of the older groups was marked, work relief being reported for only 0.5 per cent of those graduating from 1930 to 1932 as against 1.0 per cent of those graduating from 1915 to 1929. By

. In this survey, work relief is defined as emergency employment, usually nade available on the basis of need, by such agencies as C.W.A., F.E.R.A., nd W. P. A. It does not include engineering work on P. W. A. projects, which hould have been reported either as a form of private employment or as Governnent employment for those engineers working in the Public Works Adminisration itself. It also does not include engineers hired for strictly administrave work by the various relief administrations. There was some overreporting f work relief and a corresponding underreporting of public employment. Direct elief refers to direct financial or other assistance from any public authority.

. In New York City, direct relief appears to have been more extensive hrough the Professional Engineers Committee on Unemployment than through ublic agencies.

Table V—Median Period of Gross Unemployment,* by Age, Type of Education, and Professional Class, 1930–34

Graduating Class	Age (in Years) in 1934	Period of Gross Unemployment (in Months) of— Graduate Engineers: All Classes	Chemical and Ceramic	Civil, Agricultural and Architectural	Electrical	Mechanical and Industrial	Mining and Metallurgical
All graduating classes		11.4	9.4	11.8	11.5	11.1	12.3
Entered profession during 1930–34:							
Graduated in—							
1933–34	23–24	7.5	7.0	7.9	7.7	7.1	6.0
1930–32	25–27	11.9	10.6	11.9	13.2	11.1	11.9
Entered profession in 1929 or earlier:							
Graduated in—							
1925–29	28–32	12.1	11.1	12.2	12.4	12.0	11.7
1915–24	33–42	13.4		12.9	14.1	15.2	
1905–14	43–52	17.8	11.4	17.0	20.7	18.5	17.4
Prior to 1905	53+	23.1		22.9	25.3	22.2	

Year of Birth	Age (in Years) in 1934	Period of Gross Unemployment (in Months) of— Other Engineers, College Course Incomplete: All Classes	Civil, Agricultural, and Architectural	Mechanical and others	Noncollegiate Technical Course
All ages		16.3	15.8	16.9	17.3
Entered profession during 1930–34:					
Born in—					
1910–14	20–24	12.5	13.8	11.4	15.0
1905–09	25–29	14.0	13.9	14.3	15.3
Entered profession in 1929 or earlier:					
Born in—					
1900–04	30–34	14.2	13.2	15.1	16.0
1895–99	35–39	14.6	14.1	15.3	14.7
Prior to 1895	40+	19.4	18.3	22.0	19.2

* Includes periods both of direct relief and work relief.

No figure is shown in the table for engineers with a secondary-school education, for its significance is not certain. The median period for such engineers was 12.4 months.

December 31, 1934, this situation had been reversed and there was a larger proportion on work relief among the recent college graduates than among those who had entered the profession prior to the depression. This was especially true of the civil engineers, for whom work relief on December 31, 1934, was reported for 9.4 per cent of those graduating in 1933–34 and 8.3 per cent of those graduating in 1930–32, in comparison with only 6.5 per cent of those graduating in 1915–29 and 4.9 per cent of those graduating prior to 1915. In the other professional groups no real differences between the early and late graduating classes appears. Of the engineers in professions other than the civil-engineering group, who graduated during the years 1930–32, 2.2 per cent were on work relief, but 3.2 per cent of those graduating in 1933–34 reported work relief. In this connection it must be recalled that in 1934 there was a larger proportion of unemployed among those graduating in 1933–34 than among the other age groups.

Thus far, in this section, the discussion of work relief has been confined to the reports for specific dates. For the 5-year period as a whole, a larger number of engineers had some experience with work relief. For all types of engineer, irrespective of background, about 1/8 reported some period of work relief, but very wide differences were shown in the extent of work relief for civil engineers and for other types of engineers. Thus, among engineers with an incomplete college course, 19.6 per cent of the civil-engineer group reported some work relief, whereas only 7.5 per cent of those in the other professions considered together so reported. Among college graduates work relief was reported by 18.3 per cent of the civil engineers and only 10.9 per cent of the mining and metallurgical engineers. For the other professional classes, the percentages were 9.3 for electrical engineers, 8.7 for mechanical and industrial engineers, and 6.6 for chemical and ceramic engineers.

In all professional classes, age was an important factor in the frequency of work relief. Table VII gives for the 3 professional classes civil, electrical, and mechanical engineers, the percentages of those receiving work relief, at any time during the 5 years, 1930–34, classified by age. The figures relate only to college graduates.

The median period of work relief was approximately 5 months, as shown in table VII for college graduates classified by year of graduation in the 3 professional groups of civil, electrical, and mechanical engineering.

The differences in the length of the period between the various professional classes are small and show no particular regularity. Essentially, the periods are the same both for civil engineers and for mechanical engineers, though the average period was perhaps somewhat shorter in the case of electrical engineers. Little difference is shown between those who graduated from 1915–29 and those who graduated prior to 1915, but apparently those who graduated prior to 1930 had a slightly longer period of work relief than those who graduated in 1930–32.[6]

Thus far in this discussion, those reporting work relief have been regarded as unemployed. More than 4/5 of those who reported a period of work relief also reported a period of unemployment. However, among the 5,349 engineers with college degrees who reported a period of work relief, 966 reported a period of work relief but no period of unemployment. This situation calls for some explanation though it does not change the general outline of the conclusions reached. There seems to be a slight overreporting of work relief and, therefore, a slight overestimate of unemployment due to the method of adding together periods of unemployment without work of any kind and periods of work relief to determine the gross frequency and period of unemployment. There is also a corresponding underreporting of nonrelief public employment. In this discussion, it is necessary to distinguish 3 age groups, those graduating in 1929 or earlier, those graduating in 1930–32, and those graduating in 1933–34. Among the more recent graduates little difference is found between civil engineers and all other types of engineers, as regards work relief without unemployment. Of the 1,138 engineers graduating from college in 1933–34 and reporting some work relief, 333 reported no period of unemployment, that is, approximately a third of them appear to have entered directly into work relief. Among those graduating in 1930–32, 281 out of 1,747, or somewhat more than 1/6, reported such an

Table VI—Percentage Distribution of Engineers Graduating From College Prior to 1930, by Period of Unemployment

Year of Graduation	Total Reporting in Survey	Total Reporting Unemployment at Any Time During 1930–34: Number	Total Reporting Unemployment at Any Time During 1930–34: Per Cent	Per Cent Whose Reported Unemployment (in Months) Was— Under 6	6 and under 12	12 and under 18	18 and under 24	24 and under 30	30 and under 36	36 and under 42	42 and under 48	48 and over
All years prior to 1930	24,853	6,965	100.0	21.0	21.6	16.5	12.8	9.5	7.1	5.1	3.2	3.2
1925–29	6,499	2,340	100.0	23.9	25.7	19.4	13.4	7.9	4.0	3.2	1.6	0.9
1915–24	8,298	2,245	100.0	23.3	22.9	16.1	11.4	9.4	7.3	4.4	3.0	2.2
1905–14	6,602	1,570	100.0	17.7	18.8	14.0	13.8	11.4	8.7	7.2	3.7	4.7
Prior to 1905	3,454	810	100.0	12.8	11.7	14.4	13.1	10.6	12.0	8.3	7.0	10.1

6. If it is correct to conclude that the major part of the work-relief experience came in the years 1933–34, the differences between the classes graduating in 1930–32 and those graduating earlier are not to be explained in terms of a longer period of eligibility for work relief. It may be pointed out that a shorter period in the case of the classes of 1930–32 is consistent with the earlier conclusion that recruitment was more extensive among this group of engineers than among the older ones. The still shorter period, which is indicated for those who graduated in 1933–34, may well be explained by the fact that they had a shorter period of eligibility for work relief.

experience. This may merely reflect a need for young engineers to staff minor supervisory positions on projects conceived to meet the needs of other groups.

In the case of those civil engineers who graduated in 1929 or earlier years, 242 of the 1,476 who reported work relief did not report a period of unemployment. There are too few cases in the other professional classes to warrant a breakdown, but among all engineers other than civil engineers graduating in 1929 or earlier, 110 out of 988 reported no period of unemployment. Two factors lead to the belief that some of those reporting a period of work relief but no period of unemployment should be separated from the unemployed: (1) It may be noted that this situation was commoner among civil engineers than among the other professional classes, undoubtedly because the training of civil engineers was more extensively required on work-relief projects than was the training of other types of engineer. (2) It seems probable that there was some misunderstanding by engineers replying to the questionnaire and that a few reported

Table VII—Per Cent of Graduate Engineers, by Year of Graduation and Professional Class, Reporting Work Relief at Any Time, 1930–34, and Median Period of Work Relief

Year of Graduation	Per Cent Reporting Work Relief			Median Period (in Months) of Work Relief		
	Civil	Electrical	Mechanical	Civil	Electrical	Mechanical
All years	18.3	9.3	8.7	5.0	4.4	4.9
1933–34	26.4	12.5	10.2	4.1	3.8	4.1
1930–32	25.2	12.8	10.4	4.8	4.3	4.5
1915–29	15.9	6.2	7.4	5.6	4.6	5.7
Prior to 1915	12.4	6.3	7.6	5.5	6.5	5.6

The civil engineers here tabulated do not include architectural and agricultural engineers, nor do the mechanical engineers include industrial.

public administrative employment in connection with work-relief projects as work relief rather than as public employment. It is possible that certain engineers reporting a period of work relief neglected to report a period of unemployment or merged the 2 figures in a single one of a period of work relief.

In general, a period of work relief was associated with a reported period of unemployment. This was true of more than 85 per cent of the engineers, without regard to professional classification, graduated in 1929 or earlier years, who secured work relief. For this group of college graduates, there is a clear relationship between the period of unemployment and entrance into work relief.[7] The percentages in table VIII represent the ratio of the total number of individuals receiving work relief after a given period of unemployment to the total number of unemployed persons who had at least as much as the shortest period of unemployment indicated. Thus, for example, 6 per cent of all civil engineers who reported any period of unemployment whatsoever were placed on work-relief projects after a period of less than 6 months of unemployment, etc.

During the 5-year period, placement on work-relief

Table VIII—Per Cent of Unemployed Graduate Engineers on Work Relief After Specified Unemployment, 1930–34, by Years of Graduation

Year of Graduation	Per Cent of Engineers Who Received Work Relief After Specified Months of Unemployment							
	Less than 6	6–12	12–18	18–24	24–30	30–36	36–42	42–48
All classes of engineers	4.3	9.3	12.6	13.7	14.9	18.4	18.0	18.8
Civil engineers	6.0	11.9	15.7	17.9	18.1	22.1	21.2	24.6
1925–29	6.3	13.8	17.4	25.8	25.2	26.0	33.0	63.0
1915–24	7.2	13.5	19.5	20.9	19.8	36.0	28.0	27.0
1905–14	5.9	11.0	14.4	16.6	19.0	15.6	22.0	23.0
Prior to 1905	1.8	6.4	9.0	8.5	10.6	16.8	13.0	18.0
Other professional classes	2.8	7.0	9.9	10.2	12.5	15.5	15.5	14.1
1925–29	2.5	7.4	10.6	11.2	13.5	19.6	20.0	20.0
1915–24	3.7	7.5	12.4	12.7	11.8	19.3	20.0	8.0
1905–14	2.8	7.1	8.5	9.1	15.2	14.0	10.0	19.0
Prior to 1905	0.8	4.5	5.4	5.9	8.4	9.7	14.0	12.0

projects rose steadily as the period of unemployment was lengthened. This increase reflects the actual course of events in these 5 years, but the period was not homogeneous as regards the availability of work relief, which was first inaugurated on a large scale in 1933. Any person unemployed for as little as 6 months in 1931 had virtually no opportunity to secure work relief. On the other hand, a person who became unemployed in July 1931 probably would have found C.W.A. work, after the lapse of 30 months. Therefore, in interpreting the figures shown in table VIII, it must be remembered that longer periods of unemployment increase the probability of work relief merely by carrying over into a period in which work relief became available.

A further and more significant comparison may be made with reference to the availability of work relief to the members of the different groups of graduating classes. For this purpose, these classes should be interpreted as indicating not particularly differences between younger and older engineers, but more especially probable differences in the financial resources of the different groups. In the aggregate, those engineers who graduated prior to 1905 probably had substantially larger financial reserves than those who graduated from 1925 to 1929. In the case of civil engineers, the percentage on work relief was highest for those who graduated from 1925 to 1929. Among the other professional groups, this relationship was less well maintained, although there appeared to be a distinct demarcation between those who graduated prior to and after 1915. The strongest contrast was between those who graduated in the period 1925–29 and those who graduated prior to 1905.

7. For the correlation of the period of unemployment that antedates relief, the following information is available: The total period of unemployment, exclusive of work relief, and the total period of work relief. In order to simplify the presentation, the material is presented as though there were in all cases a sequence of an unbroken period of unemployment followed in certain instances by work relief. It is quite possible that in certain instances the total period of work relief is broken into several stretches interspersed with periods of work relief. In such a case, it would be incorrect to say that work relief followed after 12 months of unemployment if 12 months were the total reported period of unemployment exclusive of work relief. To distinguish several periods of unemployment would have required a greater refinement than it was possible to undertake by the questionnaire method. The extent of the error, which is implied in this assumption, is probably not great, but technically all that can be shown is a relationship between a certain aggregate period of unemployment, exclusive of work relief, and the existence of some period of work relief which may have preceded a period of unemployment or have broken into a period of unemployment.

Switchboards for Boulder Power Plant

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Switchboards for the power plant at Boulder Dam are unusual not alone for their size, but also for the combination in one plant of switchboard designs and methods that have been used individually but seldom together. The plan of the power plant and the switchboards and control equipment are described in this paper.

THE Boulder Power Plant is unusual in many respects, and these unusual features are reflected in the switchboards. Mere "bigness" would not make the switchboards unusual, but other features resulting indirectly from such bigness introduce requirements in the switchboard design which are not commonly encountered. Among the well-known features of this plant are:

Generating units of 3,000, 40,000, and 82,000 kva

Transformer banks up to 165,000 kva and 287.5 kv

Ultimate capacity of 17 major generating units totaling approximately 1,300,000 kva

Among the lesser known or recognized features are:

The generators are disposed along the opposite sides of the river so that the power plant is in effect approximately 1,600 feet long, with the control room in the center. The farthest generator is approximately 700 feet from the control room.

The 287.5-kv substation or switch yard for the City of Los Angeles is approximately 1,500 feet from the control room.

The complete plant will involve 4 major systems, with transmission voltages from 132 kv up to 287.5 kv.

The Boulder Power Plant really represents several large generating stations, tying in with separate outside systems. The individual requirements of these systems must be taken care of with an over-all uniformity in operating practice and switchboard design. Standard, conventional switchboard design has been followed wherever possible. Nevertheless the very features previously mentioned necessitate the combination in one plant of switchboard designs and methods which have been used individually, but seldom together in the same plant.

The initial installation comprises 4 82,500-kva units for the City of Los Angeles, and 1 40,000-kva unit for the Southern Sierras Power Company. The plan adopted for these units will apply in general to the succeeding units. The general plan is to provide a separate switchboard or cubicle near each generator for manual control. There is also a centralized main control desk from which all the generators, transformers, and their related apparatus may be controlled automatically and remotely.

In brief, the City of Los Angeles system involves connecting 2 generators in parallel to a transformer bank, through suitable low-voltage circuit breakers. The transformers are located directly outside the generator room, and the low-voltage circuit breakers are located in suitable switch rooms, directly outside the main building, and as close to the respective generators and transformers as is possible. The high-voltage side of the transformer bank connects to a double-bus outdoor substation, from which are taken the Los Angeles lines. Each generator has 2 breakers in parallel so as to permit maintenance without interruption of service. Provisions are made for connecting a spare generator to a transfer bus, and energizing a transformer therefrom, in order to replace any generator that may be out of service.

Generator Control Cubicles

The control system is arranged so that the generators may be operated from 2 locations, either the control room or the generator floor. Each generator control cubicle is located in a recess in the river wall of the power plant. It is provided with all the manual control and instrumentation usually associated with a water-wheel generator of like capacity such as circuit breaker, field, and governor controls. At this point the generator can be completely started even to synchronizing and connecting to the bus, controlled, and shut down. This permits and facilitates initial operation, testing, and maintenance, and provides emergency operation in case the main control desks should be out of service. Control is not provided for the high-voltage circuit breakers and disconnecting switches, but suitable signals indicate their connections. The voltage regulator, generator protective relays, and various graphic instruments are also located on this board.

This cubicle also serves as the transfer point for the control circuits coming from the main desk. Therefore, the interposing relays, interposing current transformers, automatic starting relays, and thermal converters for load control and totalizing are located here. A control-transfer switch determines whether the unit can be controlled locally or from the main control desk and thus prevents conflicting, contradictory, or incomplete control. This switch is provided with a cylinder lock to prevent unauthorized operation.

Main Control Room

The contracts for power privileges established 2

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principal lessees, the City of Los Angeles and the Southern California Edison Company, as the generating agents for generation of all power at Boulder Dam. The City of Los Angeles generates power for itself, the Metropolitan Water District, the cities of Pasadena, Glendale, and Burbank, and the states of Arizona and Nevada. The Southern California Edison Company generates power for itself, and the Southern Sierras Power Company. The main control room is divided into 2 sections to provide for separate operation by the 2 lessees. These rooms are located in the central portion of the power plant at an elevation approximately 70 feet above generator floor level. In the control room for the City of Los Angeles, the main control desk and the station service desk face each other from opposite sides of the room. The auxiliary control room boards are located on the other 2 sides of the room. The operator's desk, supervisory control benches, etc., are located in the center of the room, between the control desks. The equivalent equipment for the Southern Sierras Power Company is located in the adjoining room with provision for future equipment for the Southern California Edison Company.

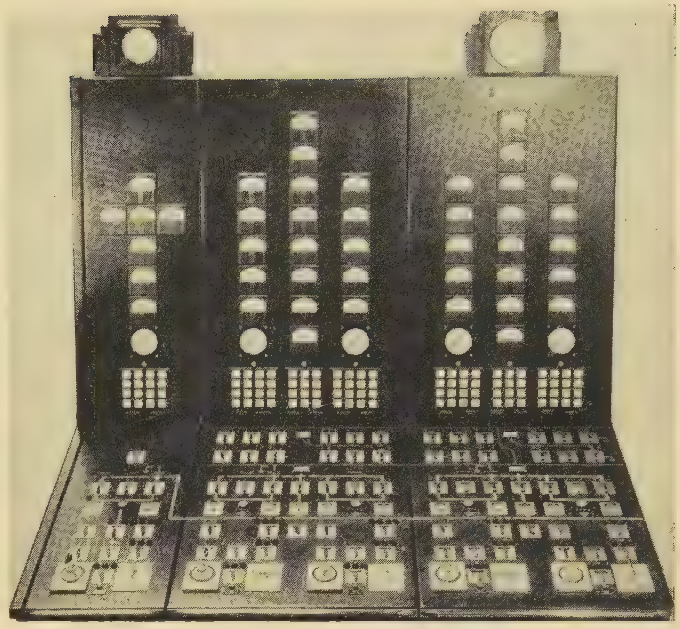


Fig. 2. Main control desk, showing 3 panels with the control for 5 generators (one future) and 2 transformer banks

Main Control Desk

The main control desk centralizes the control of all the main generators, the power transformer banks, and the outgoing feeders. The desk for the City of Los Angeles comprises initially 3 fully equipped sections for the control of 5 generators, 2 transformer banks, and 2 outgoing lines. The initial desk for the Southern Sierras Power Company comprises a single section, mounted separately, for the control of 2 generators with their respective transformers and transmission lines. On account of the large number of units to be controlled, the desks are of the so-called "miniature" type, using Westinghouse type *K* indicating instruments 4 inches wide with scales $3^1/_2$ inches long, and control switches of the Minatrol type. With complete control and instrumentation including lamp indicators, miniature bus, governor controls, etc., the length of the Los Angeles section for the initial equipment of 5 generators, 2 transformers, and 2 lines is only 6 feet.

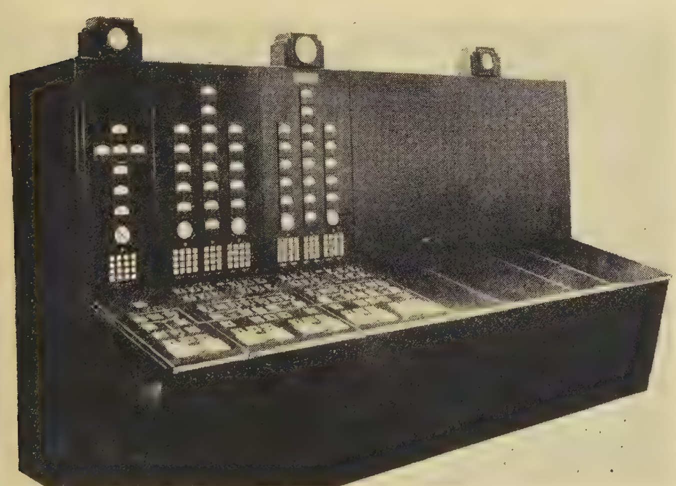


Fig. 1. Complete main control desk

Starting from the main control desk is almost completely automatic. The operator selects the breaker with which he plans to connect the generator to the bus, inserts the key for one of the 2 automatic synchronizers, and turns the master control switch to "start." Auxiliaries such as the bearing oil pressure pump, cooling water pump, etc., start automatically and when these are in operation, the turbine gates open. The generator then comes up to full speed, taking full voltage excitation, matches speed with the system and synchronizes, resulting finally in closing the preselected breaker. A synchronizer by-pass button is provided for manual synchronizing when the bus is dead or when the automatic synchronizer is out of service. This performance is carried out through a full complement of preventive interlocks and relays and continuous operation is safeguarded by means of protective relays operating as functions of electrical conditions in the main circuits, temperature, or in failures of the auxiliary devices. With one circuit breaker closed, the parallel breaker can be closed by the operator directly and immediately.

The high-voltage transformer or line circuit breakers can be handled manually, either after the generator has been put on the bus, or preset so that line connection is made on the low-voltage side automatically.

Once on the line, the operator can control the load, voltage, or regulated voltage level, etc., as in a conventional power plant. Shutdown can be made by the operator, or result from the operation of the protective relays. Most of the automatic and pro-

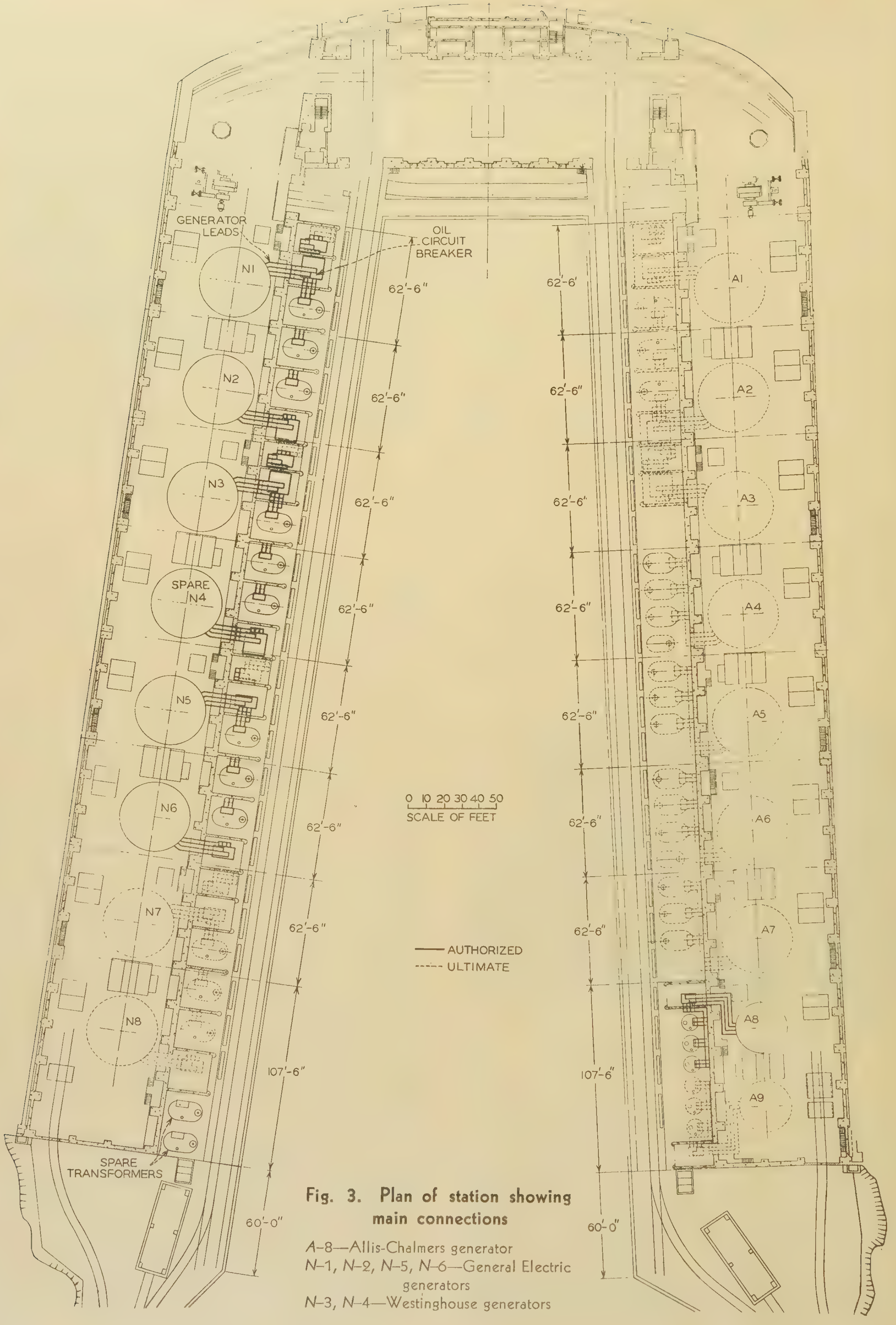


Fig. 3. Plan of station showing main connections

A–8—Allis-Chalmers generator
N–1, *N*–2, *N*–5, *N*–6—General Electric generators
N–3, *N*–4—Westinghouse generators

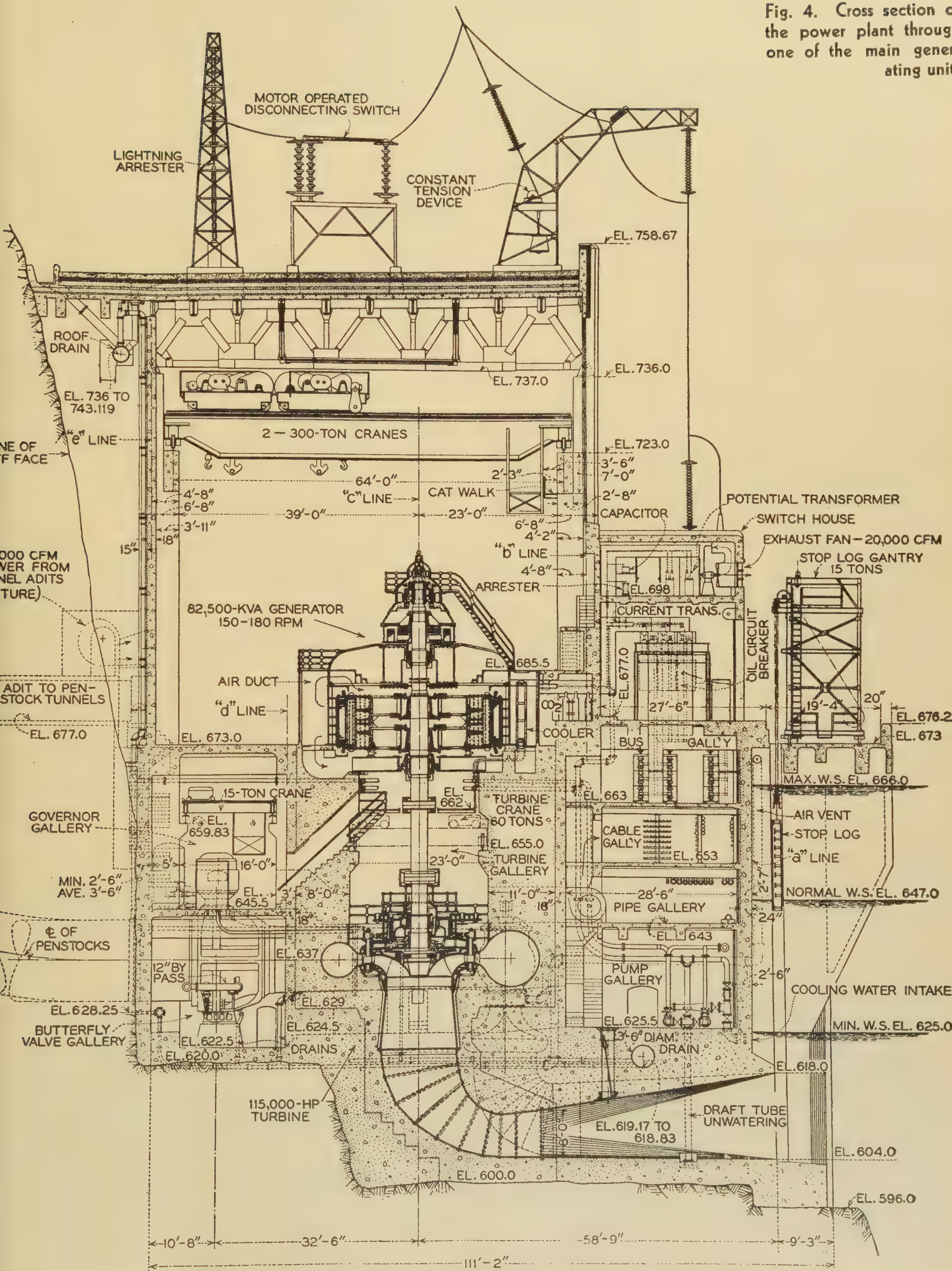


Fig. 4. Cross section of the power plant through one of the main generating units

tective features found only in an unattended station have been incorporated in this control in order to relieve the operator as far as possible from routine duty.

The control desk is constructed of "stretcher leveled" (smoothly finished) steel, with the back fully enclosed and provided with swinging doors. The front lower face is inclined toward the rear so as to facilitate approach to the desk and manipulation of the various controls thereon. Another unusual feature of this desk design is the arching of all internal cross members and corresponding placement of control conductors, so that an inspector can walk along the top of the terminal boards on the lower floor, and readily observe or adjust the apparatus and wiring on the under-inner side of the desk.

Station Service Control Desk

The station service control desk is similar in construction and equipment to the main control desk. The 3 central sections are of full height, and are for the control of the 2 3,000-kva station service generators and the station service transformer bank. These sections are provided with complete instrumentation and control comparable to that provided for the main generators. Automatic starting, speed matching, and synchronizing are provided for these generators as is the case with the larger generators.

The control desk sections extending from each side of the center are of lower height, because of the relatively fewer instruments required thereon. These sections are for the control of the storage batteries and their charging generators, 2,300-volt feeders to various sections of the plant and to the 460-volt auxiliary transformers for station service. The outside sections, toward the Arizona and Nevada sides respectively, are provided with illuminated signals to indicate normal or abnormal conditions with respect to the various auxiliary services such as control supplies, cooling-water indications, bearing-oil indications, etc.

All controls from the main desk are at 125 volts direct current. These controls operate interposing relays located at their respective generator cubicles, or at the outdoor substation, translating to the heavier currents required for the various devices such as governor controls, and also to the 250-volt d-c control for the circuit breakers and similar apparatus.

For the various indicating and graphic instruments, potential is brought from the generator cubicles at full value of 110 volts. For the current instruments and similar devices, the normal 5-ampere secondary current is stepped down to 0.1 ampere by current transformers located at the generator cubicles or at the switch yard. By this means, the long control and instrument cables from the control desk to the generator cubicles or the switch yard are kept to a reasonable size, and excessive current-transformer burdens are avoided.

Auxiliary Control Board

There are 2 auxiliary control boards each consisting of a double line of vertical panels, arranged back-to-back with a passageway between. These panels are equipped with the master automatic equipment used for the entire plant, that is, speed matchers and

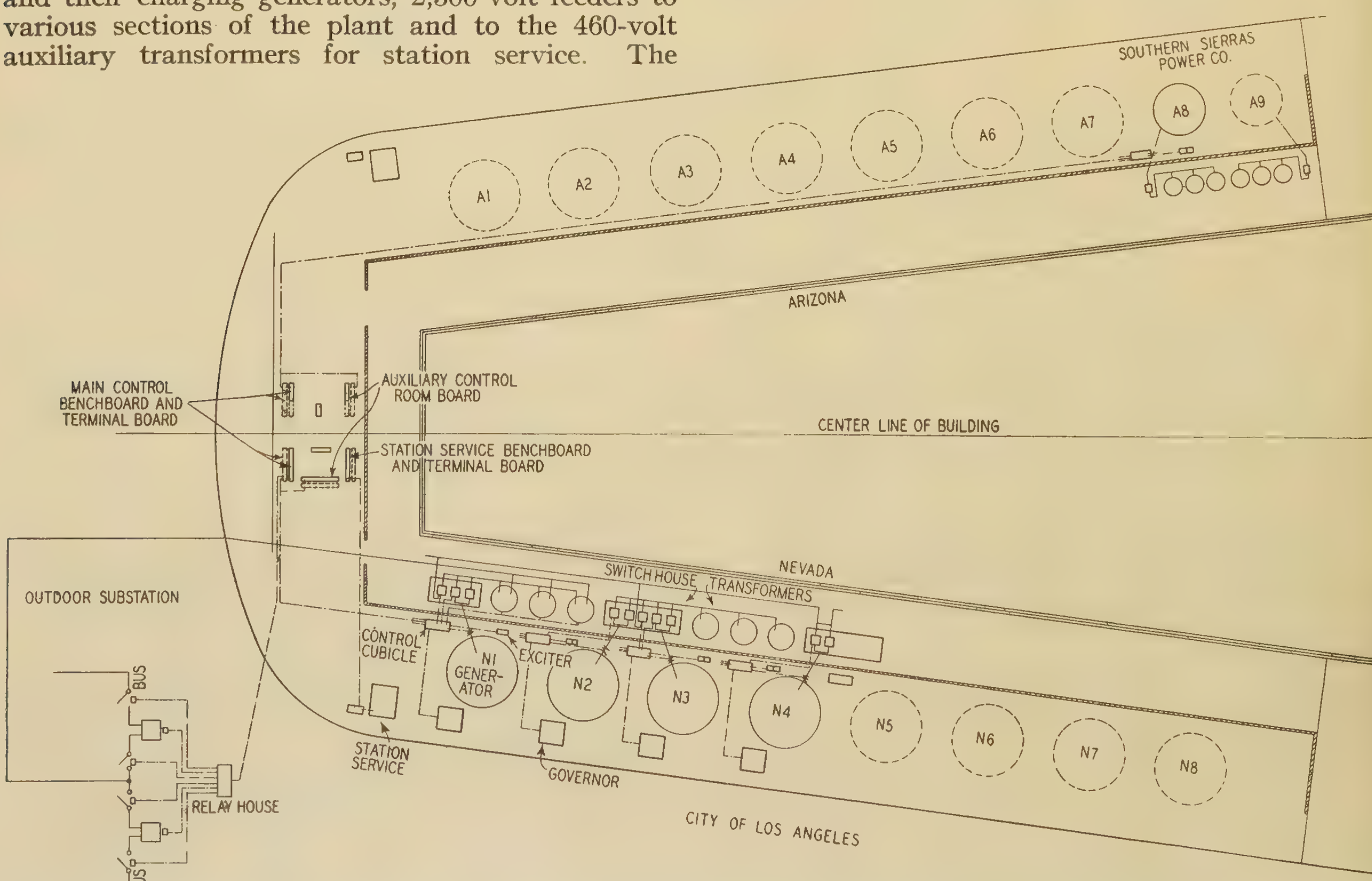


Fig. 5. Schematic plan of the station, showing interconnections from control desk to the cubicles and outdoor substation

synchronizers and frequency and load controls; with recording instruments for generator-armature and field-winding temperatures, bearing temperatures, and transformer temperatures; with frequency, totalizing, watt, and reactive kilovolt-ampere recording instruments; and with voltmeters for automatic recording of high voltage during faults.

Terminal Boards

The control and instrument cables from the various cubicles, switch yard, station service switchgear, and station auxiliary switchgear are brought to terminal boards in a room below the main control room and located directly beneath the control desks or auxiliary boards which they serve. Vertical cables connect directly from the terminal blocks in the terminal boards to the terminal blocks in the switchboards above.

The terminal boards for the control desks are actually double units, mounted back-to-back, and running lengthwise under their respective desks, with a passageway between. Terminal blocks and test switches are mounted on one side, and small circuit breakers for the complete segregation of the 125-volt control circuit in the desks are mounted on the other side. The terminal boards for the auxiliary boards are similar, except that test switches and circuit breakers for control segregation are omitted.

Control Supply

The control supply for the desks is provided by a 60-cell 125-volt storage battery, with suitable motor-generator charging equipment. The various circuits to the switchboard desk section are supplied through individual circuit breakers. Not only is the supply segregated for each main unit, but also for each distinct part of the unit. The completeness of this segregation may be indicated by the fact that 38 2-pole circuit breakers are required for the control circuits of one desk section controlling 2 generators and one transformer. This segregation permits of complete isolation automatically in case of a fault and manually for maintenance purposes. While these circuits are only 125 volts direct current their importance and the possibilities of high short-circuit currents led to the choice of Westinghouse type *AB* automatic thermal-trip circuit breakers of 250-volt d-c rating and 10,000-ampere rupturing capacity.

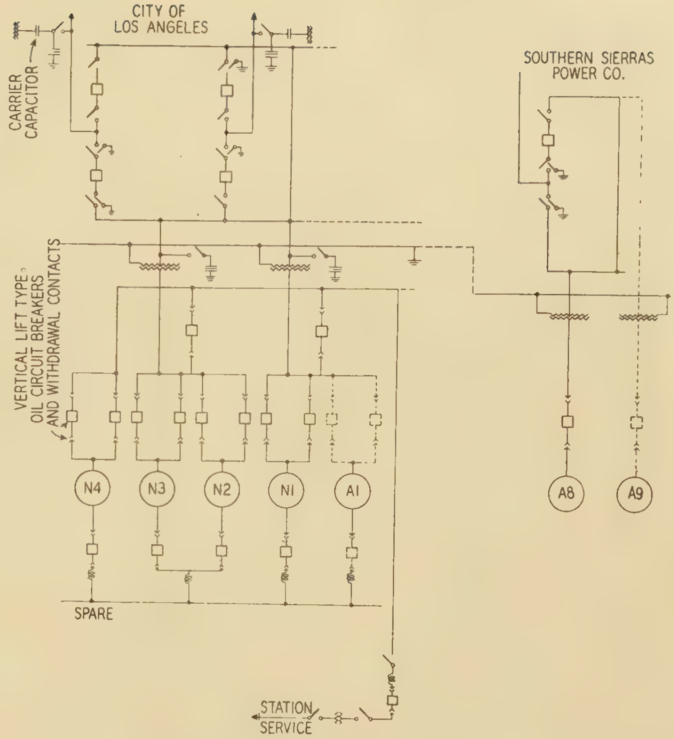


Fig. 6. Simplified single-line diagram of present equipment

Oil circuit breakers and similar apparatus are operated from 120-cell 250-volt batteries, one for each wing of the power plant, and for the switch yard. These control circuits are similarly segregated, not

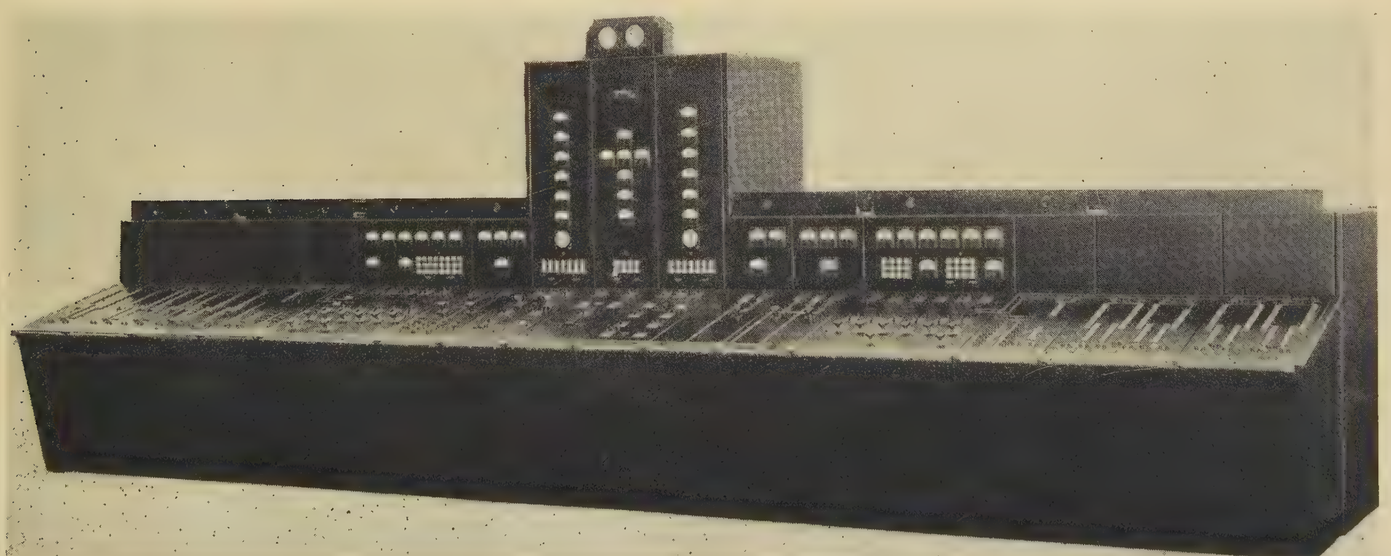
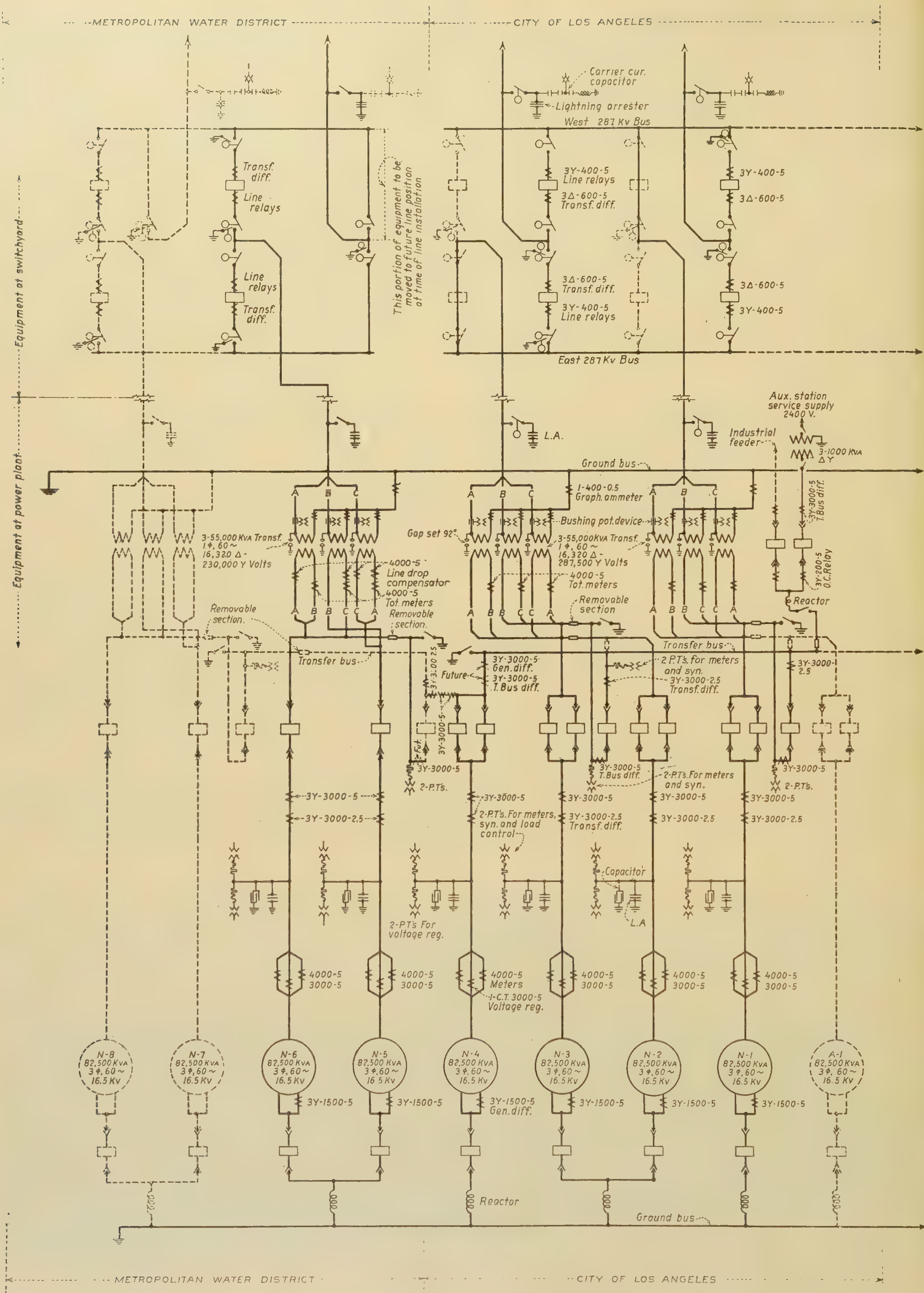


Fig. 7. Front view of station service control desk



METROPOLITAN WATER DISTRICT
CITY OF LOS ANGELES
Carrier cur. capacitor
Lightning arrester
West 287 Kv Bus
Transf. diff.
Line relays
Line relays
Transf. diff.
This portion of equipment to be moved to future line position at time of line installation
3Y-400-5 Line relays
3Δ-600-5 Transf. diff.
3Y-400-5
3Δ-600-5
3Δ-600-5 Transf. diff.
3Y-400-5 Line relays
3Δ-600-5
3Y-400-5
East 287 Kv Bus
Equipment at switchyard
Equipment at power plant
L.A.
Aux. station service supply 2400 V.
Industrial feeder
3-1000 KVA ΔY
Ground bus
1-400-0.5 Graph. ammeter
Bushing pot. device
Gap set 92°
3-55,000 KVA Transf. 1 ϕ, 60 ~ 16,320 Δ - 230,000 Y Volts
3-55,000 KVA Transf. 1 ϕ, 60 ~ 16,320 Δ - 287,500 Y Volts
4000-5 Line drop compensator
4000-5 Tot. meters
4000-5 Tot. meters
3Y-3000-5 T. Bus diff.
3Y-200-5 O.C. Relay
Reactor
Removable section.
Removable section.
Removable section
Transfer bus
Transfer bus
Future
3Y-3000-5 Gen. diff.
3Y-3000-5 T. Bus diff.
2 P.T's. for meters and syn.
3Y-3000-2.5 Transf. diff.
3Y-3000-2.5
3Y-3000-5
2-P.T's.
3Y-3000-5 T. Bus diff.
2-P.T's. For meters and syn.
3Y-3000-5
3Y-3000-2.5
2-P.T's. For meters, syn. and load control
3Y-3000-2.5 Transf. diff.
Capacitor
L.A
2-P.T's For voltage reg.
4000-5 3000-5
4000-5 Meters
1-C.T. 3000-5 Voltage reg.
N-8 82,500 KVA 3 ϕ, 60 ~ 16.5 Kv
N-7 82,500 KVA 3 ϕ, 60 ~ 16.5 Kv
N-6 82,500 KVA 3 ϕ, 60 ~ 16.5 Kv
N-5 82,500 KVA 3 ϕ, 60 ~ 16.5 Kv
N-4 82,500 KVA 3 ϕ, 60 ~ 16.5 Kv
N-3 82,500 KVA 3 ϕ, 60 ~ 16.5 Kv
N-2 82,500 KVA 3 ϕ, 60 ~ 16.5 Kv
N-1 82,500 KVA 3 ϕ, 60 ~ 16.5 Kv
A-1 82,500 KVA 3 ϕ, 60 ~ 16.5 Kv
3Y-1500-5
3Y-1500-5 Gen. diff.
Reactor
Ground bus
METROPOLITAN WATER DISTRICT
CITY OF LOS ANGELES

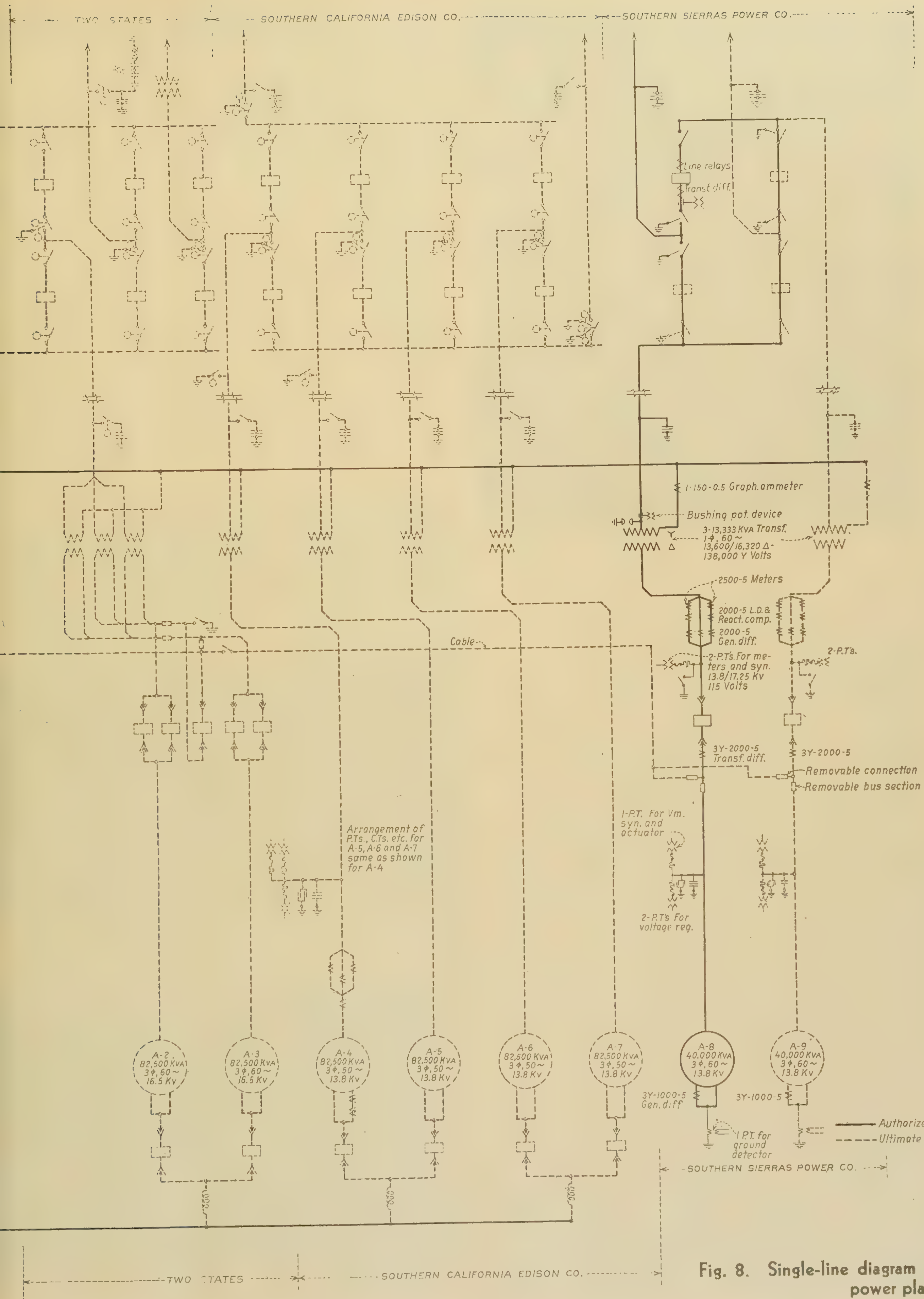


Fig. 8. Single-line diagram of power plant

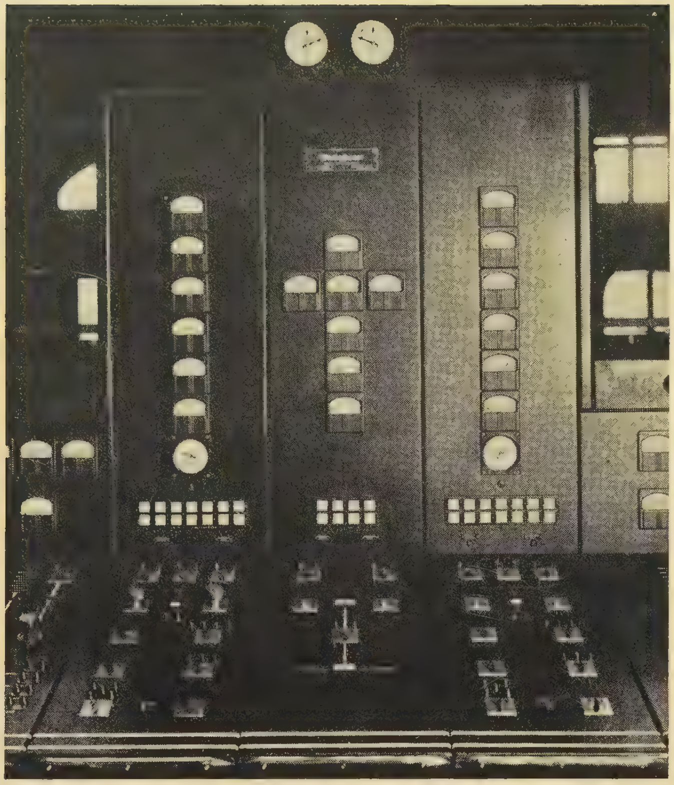


Fig. 9. Section of station service control desk

only for the individual generator or transformer units but also for the parts of the complete unit controlled. A combination of circuits is permitted only where multiple operation is required, as for the tripping of several circuit breakers from the operation of a single set of protective relays. Circuits from the 2 250-volt batteries are carried completely around the plant, so that control supply to the circuit breakers and other apparatus is always available.

Obviously, the control desk is of little value if either of the batteries is out of commission, so the usual circuit-breaker lamp indicators are connected so that a failure of either the 125-volt or the 250-volt storage battery source will put out the lights.

High-Speed Differential Protection

High-speed clearance of internal transformer and generator faults is planned in order to maintain stability at the highest possible level and to limit the damaging effect of internal fault currents. Accordingly, the high-voltage oil circuit breakers on the 287-kv transformer bank will clear the fault in 3 cycles, and low-voltage breakers for the generators and the transfer bus will clear in 8 cycles. The differential relays for both the transformers and the generators will operate in approximately one cycle under fault conditions. These relays are of the balanced-beam type with low burden characteristics. The transformer relays are provided with self-contained voltage and timing interlocks so as to avoid operation and false tripping on the magnetizing-current rushes, either when the transformer banks are energized or as a result of recovery voltages following the clearance of an external fault, without introducing any delay in the event of a fault within the differential area.

The transformer differential relays will trip out all the circuit breakers feeding the transformer on both the high-voltage and low-voltage sides. The generator differential relays will trip not only the generator circuit breakers, but also the neutral and field breakers, shut down the water wheel, and release carbon dioxide into the generator housing. The low-voltage current transformers are located to provide overlapping protection zones, leaving no section unprotected.

Differential relay operation in one cycle introduces hazards of false tripping resulting from faults external to the protected zone. The balancing of dissimilar current transformers, unequal loading of transformers in parallel or divided power circuits, high ratio of fault to normal current, or slowly decaying d-c component of the external fault current may separately or jointly effect a saturation of the various current transformers, and thus unbalance the secondary currents to cause relay operation when no such operation should occur. The importance of these factors is evident when it is considered that the relays must determine whether the fault is within or beyond the transformer or generator and then operate in one cycle for an internal fault.

If the current transformers for the high-voltage side of the transformer are located in the circuit

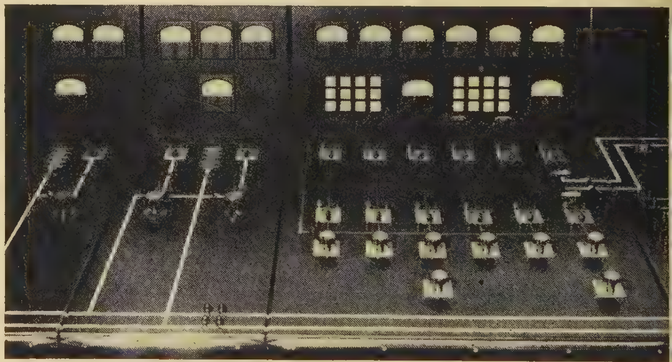


Fig. 10. Section of station service control desk

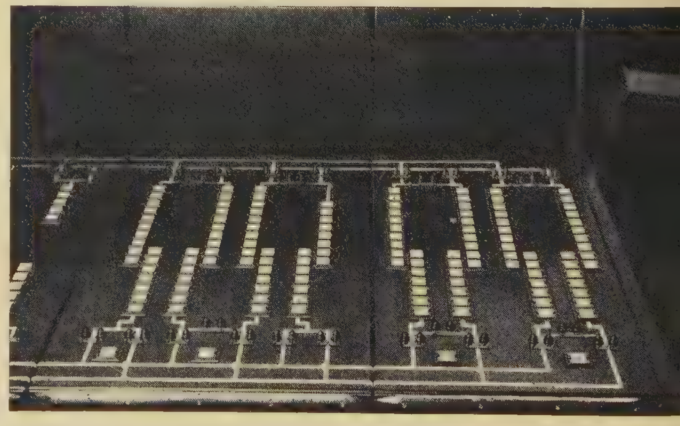


Fig. 11. Section of station service control desk

breakers of the double bus system, the current flowing in any given current transformer may be considerably larger or smaller than the current flowing through the transformer bank being protected because of current passing from one bus to the other. The restraint in the differential relay is very closely proportioned to the current flowing through the transformer bank, but the current tending to produce saturation in any given current transformer may be larger than this by the current flowing from one bus to the other through the transformer breakers. This would result in the current tending to produce saturation being much larger than the current to prevent the relay from operating.

The result of the d-c component of the short-circuit current and its low rate of change is to require a large total flux in the current transformer to transform this component from the primary to the secondary. If the flux required exceeds the saturation point for the current transformer, the latter will saturate during part of the short circuit, which in turn will cause the transformer to draw an excessive exciting current both for the d-c component

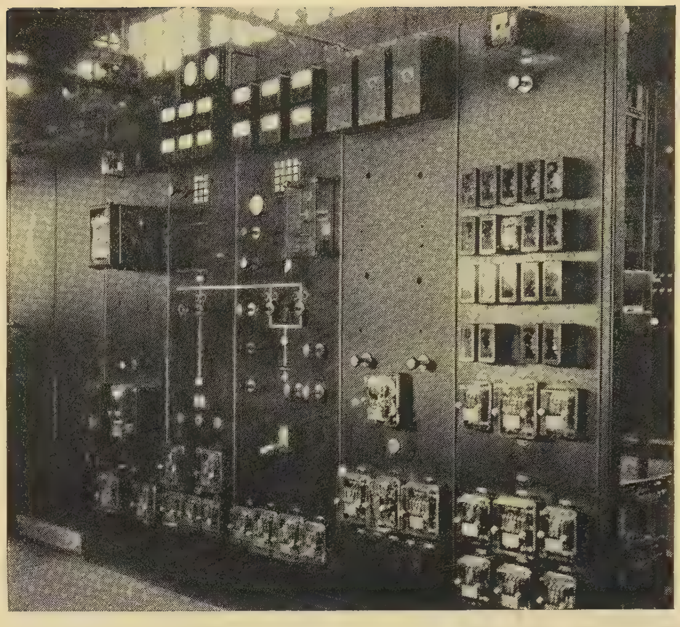


Fig. 13. Front view of cubicle of generator N–3

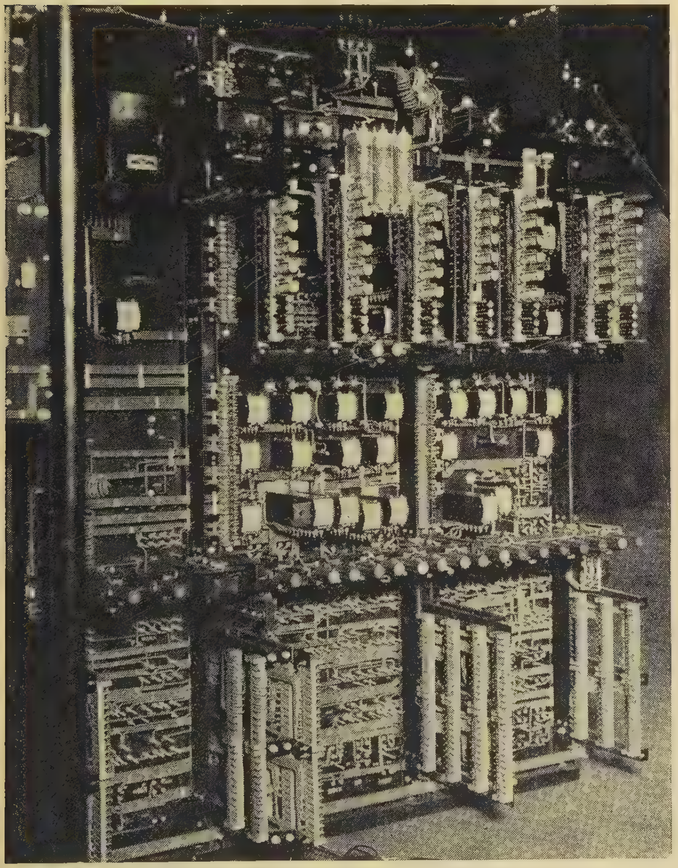


Fig. 12. Rear view of station service control desk

and for the a-c component being transformed at the same time. This results in a departure from ratio which can be very large in the most severe cases. Unless all the current transformers involved in the differential protection are affected in the same way and to proportionately the same extent, departure from ratio of one or more of the current transformers will result in current through the differential relay with some hazard of incorrect operation.

Referring particularly to the transformer protection, it is recognized that fully asymmetrical short circuits occur only infrequently, particularly on high-voltage faults, and likewise the worst short circuits occur only at rare intervals, and therefore the conditions which contribute to improper operation may be expected only at long intervals. However, the use of highly sensitive relays, and the presence of a slowly decaying d-c component emphasize the possibilities of such improper operation. Considering the relative importance to the City of Los Angeles of Boulder Dam power, it was desirable to eliminate this hazard as far as practically possible.

A complete theoretical analysis of the entire subject, supplemented by numerous oscillographic test data, indicated that the most practical solution would be obtained by 3 distinct steps. In the first place, the amount of iron in both the high-voltage and low-voltage current transformers was increased several times beyond normal. In the second place, the amount of copper in the current-transformer secondary windings, and in the connections from the transformers to the protective relays, was increased several times beyond normal in order to decrease the burdens. Lastly, the differential relays for the power transformers were located at the switch-yard rather than in the power plant, in order to shorten the runs and decrease the burden for high-voltage current transformers where the greatest unbalance might exist. All of these steps contribute to reduce the dangers of saturating, and thus tend to give proper current transformer performance within the limits of the differential relays under both steady-state and transient conditions.

In the case of the generator relays, the same type of problem exists, but the situation is more readily taken care of because of the similarity of design of

the current transformers co-operating in the differential protection scheme.

Load and Frequency Control

Automatic load and frequency control of the most advanced and complete type will be provided for each of the initial power systems. Any of the City of Los Angeles generators can be placed on the follow-

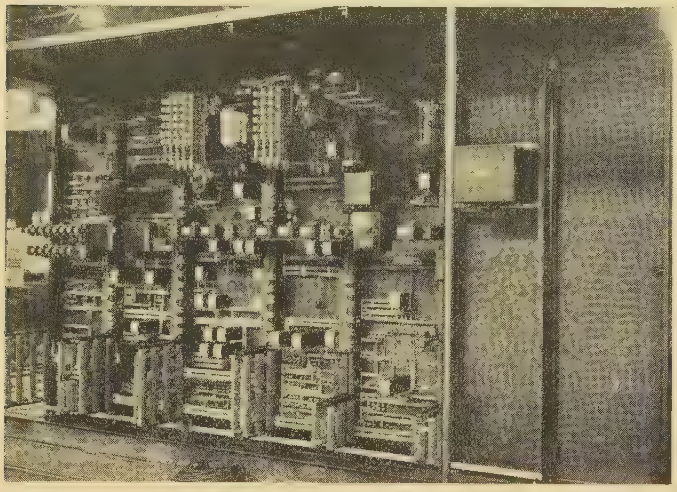


Fig. 14. Rear view of cubicle of generator N-3

ing individual types of control regardless of the type of operation chosen for the remaining generators:

1. Frequency control
2. Adjustable proportionate-load control
3. Independent base-load control

This equipment consists generally of a high-grade Warren Telechron type *E* master pendulum clock, a master frequency unit controller which can be switched to any generator unit at will, and a load controller for each unit. The master clock is separately mounted and the master frequency controller and the unit load controller together with their accessories, are mounted on the auxiliary control board. A combined system frequency and time error recorder is mounted on the auxiliary board, and a time-error indicator is mounted on the control desk. The unit load controllers are actuated by direct current obtained from "thermal converters" located at the generator cubicles.

While completely automatic load and frequency control is provided, manual control is also available, with suitable interlocking to prevent contradictory or conflicting operation and consequent "hunting" of control. In addition, the load and frequency control automatically trips off after an adjustable time delay on failure of the a-c or d-c supplies or when the frequency, unit load, or total load exceeds predetermined limits.

Clock Supply Equipment

The complete plant will have approximately 300 synchronous motors operating various clocks, graphic instrument drives, etc. These clocks and graphic instruments should be kept operating regardless of the condition of the main power system, and particularly to obtain a graphic record under fault conditions and independent of the system under fault. Accordingly, a 115-volt 60-cycle frequency-regulated single-phase supply is obtained from 2 $7^1/_2$-kva generators, each driven by a d-c motor, energized from the main control storage battery. Either set can carry the entire load of clock supply.

The generators are regulated for voltage, which varies only under starting conditions, as the clock load is uniformly constant. Frequency is regulated by field control of the motors, taken from a standard frequency generator.

The standard frequency generator comprises an electrically maintained tuning fork, a vacuum-tube oscillator, duplicate amplifiers, etc. The tuning fork with its associated oscillator generates a small amount of constant-frequency current, which is amplified to operate standard clocks, used as monitors, and to energize the grids of hot-cathode mercury-vapor rectifier tubes, which serve in the field control of the motors to maintain constant speed.

While there is only a single master tuning fork and standard frequency supply, all tubes used therein are in parallel so as to insure continuity of operation and the field controls of the motors are independent.

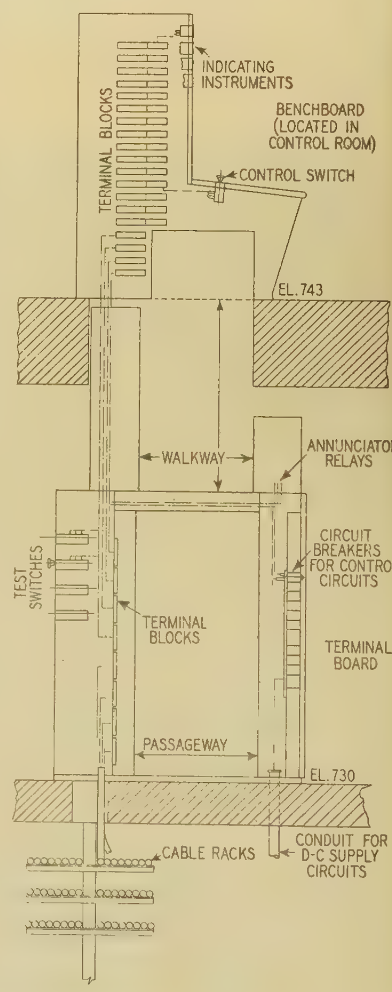


Fig. 15. Cross section showing relation of terminal boards to control desk with their interconnections

Suitable clocks are provided to check directly the output of the standard-frequency tuning-fork control, as well as the output of the motor generator set.

The equipment is expected to maintain a constant supply frequency with an error from standard time signals of less than one second per day. By checking with radio time signals, it should be possible to adjust so as to maintain the integrated time error very close to zero.

Annunciator System

A very complete annunciator and signal system is required because of the large number of generating units, distances from each other and from the main control room, different operating floors, and the possibilities of operating the generators either from the main control desk or from the generator cubicles. The principal purposes are to provide communication between the main control room and the generator and governor floors, to call the operator's attention when a unit is being started or shut down, and likewise to call attention at the various points to any so-called "trouble" operation.

Dual telephone systems provide for the usual vocal communication.

For trouble indication, each of the generators and the transformers, including those for station service,

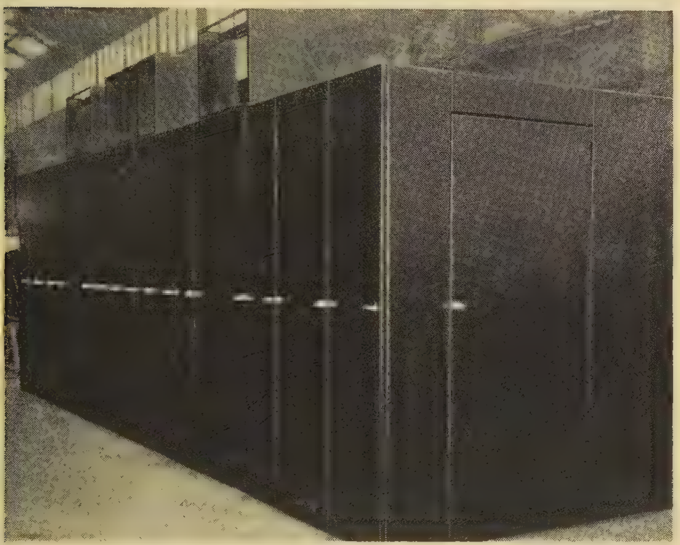


Fig. 16. Terminal boards with doors closed

is provided with an annunciator group at each of its control points. For instance, for generator N–1 there are provided an annunciator group on the main control desk, one on its generator cubicle, and one on the unit auxiliary control board in the governor gallery. In each of these groups is provided a lamp indicator to show

1. Low governor-oil pressure
2. Hot bearings
3. Generator-cooler failure
4. Hot generator windings
5. Generator cooling-water failure
6. Differential-relay operation
7. Overspeed
8. Overvoltage; direct current and several others

For each generator or transformer unit, the annunciator groups are identical, but the groups for the transformers and for the station service generators will differ slightly from those for the main generators, according to their respective needs.

Likewise on the feeder panels of the station service

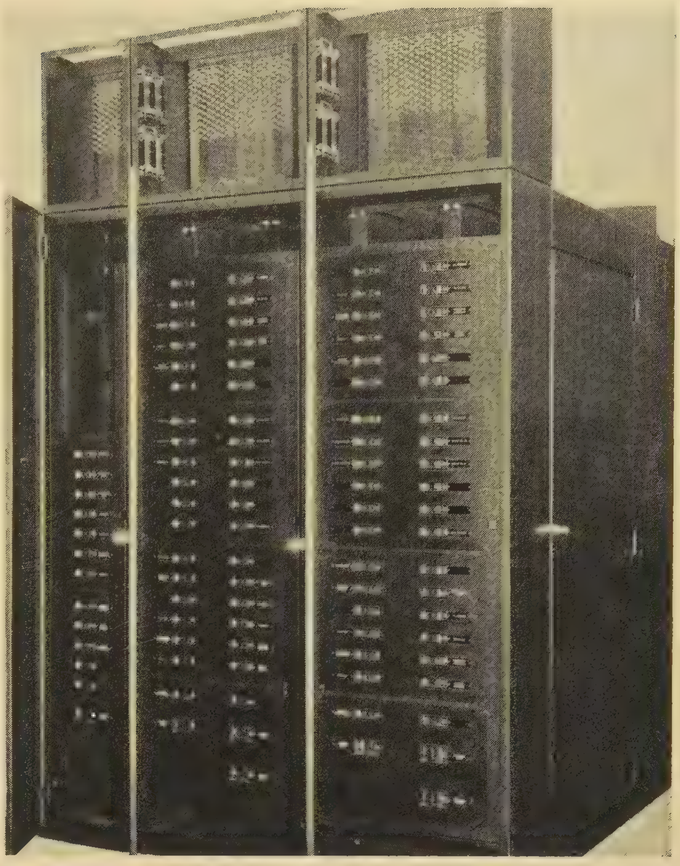


Fig. 17. Front view of terminal boards with doors open, showing control distribution circuit breakers

benchboard, there are similar annunciator groups to indicate, for instance, among others,

1. Ground on 250-volt battery number 1
2. Charger number 1 a-c supply circuit tripped
3. Nevada wing 250-volt feeder breaker tripped
4. Nevada canyon wall feeder trip
5. Feeder A to switchyard tripped
6. Feeder to N–0 to N–6 600-kva transformer tripped

In each of the generator rooms there are provided large visual indicators on the generator balcony and on the governor gallery with numerals on 3 sides and visible at a distance of 300 feet to indicate at which unit the operator is required. Attention is called to these visual indicators by suitable audible signals, one to call the operator for standby service when starting up the unit, and the other in case of trouble.

Appropriate audible signals are also provided in the main control room, with bright lamp indicators to show the unit on which trouble occurs.

The annunciator system is operated by the protective relay which functions in cases of trouble; for instance, differential relays, low oil-pressure relays, high-temperature relays, etc. The trouble relays will usually maintain their contacts until the trouble has been corrected. When trouble occurs, the audible alarms will sound in the main control room and in the generator balcony and the governor gallery. These alarms will sound for approximately 10 seconds and then will reset automatically so as to be ready for the next trouble indication. At the same time, the large visual

indicators in the galleries will show the number of the unit on which trouble has occurred. One lamp indicator in each of the corresponding groups on the generator control board panel, the generator cubicle, and the unit auxiliary control panel in the governor galleries will be illuminated. After the trouble has been cleared, the annunciator indicator lamp can be extinguished by a reset push button at each group, but any attempt to do this before the trouble contacts have opened is futile. In addition, the operation or resetting of the annunciator indicator is not permitted to interfere with the automatic release of the audible alarms and their preparedness for further signals. The resetting of the annunciator indicator is done independently in each group, without affecting the indicator at another group. Likewise, resetting the alarm and annunciator indicators for one fault does not interfere in any way with the reception of signals and indication for subsequent faults.

On the end panels of the station service control desk are provided vertical rows of signal windows, to indicate the condition of the auxiliary control necessary for the generator units. For instance, for each main generator there are provided 10 lamp indicators for the a-c auxiliaries, including among others:

Transformer cooling water
Transformer-oil circulation
Fan indication
Generator cooling-water indication
Auxiliary control transformer
Governor oil-pump indication

and 7 signal windows for the d-c auxiliaries, including among others:

Generator bearing oil-pump indications
Generator field breakers
Generator differential-relay pilot lamp

Each signal window is about one inch square and is covered with a white translucent front on which designation of the equipment it represents is lettered in black, with a low-brilliancy lamp in back to indicate a normal condition.

It is obviously impossible to go into the detail of switchboard circuits and methods for a plant of this size. The foregoing description of a few of the problems gives a measure of the complexity of the overall switchboard problem and some clue as to the completeness of the plans adopted.

Some further illustration of the problems may be obtained by considering that the electrical equipment in a plant of this size naturally represents many manufacturers. The main purpose of the switchboard is to control all of these electrical equipments, and to do so with a uniformity of methods that will facilitate operation and subsequent maintenance. For instance, the switchboards control oil circuit breakers of 3 manufacturers and air circuit breakers of 2 manufacturers. Each oil circuit breaker had originally its own control scheme, and while the distinctive features of each manufacturer have been retained, those different control schemes have been molded into an over-all uniform scheme.

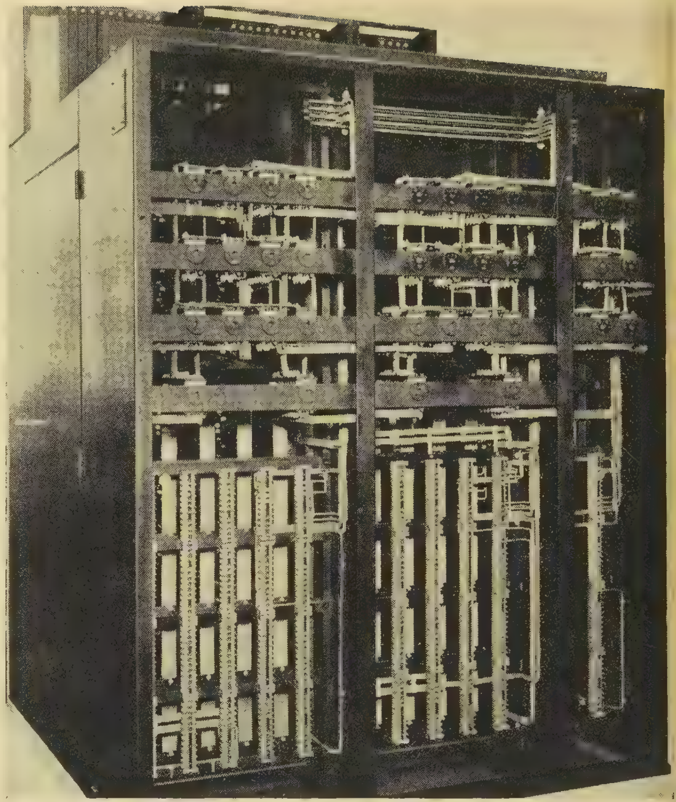


Fig. 18. Rear view of terminal board with doors removed, showing terminal blocks and test switches

Voltage regulators, load and frequency regulators, and automatic speed matcher and synchronizers are supplied by 3 different manufacturers. The switchboards provide mounting for graphic instruments from at least 2 manufacturers. All of these must be co-ordinated into a uniform and operating system.

While considerable emphasis has been given to the switchboards for the City of Los Angeles, because their 4 generating units are being controlled by the initial installation, the same features of design apply to the switchboards for the Southern Sierras Power Company.

It has been part of the fundamental plan to provide switchboards which will be complete in every detail, for every operating requirement of the best type of station, yet there is a simplicity, directness, and uniformity of design that will make operation and its attendant maintenance problems as simple as possible. The Boulder Dam switchboards are entirely modern and up to date, without departing from sound practice. They prove the feasibility of conventional switchboard design for a generating plant of this size and character.

References

[Editor's Note: The following list of papers published in Electrical Engineering on subjects related to the Boulder Canyon project is given for the convenience of those desiring further information.]

1. Power Limits of 220-Kv Transmission Lines, A. A. Kroneberg and Mabel Macferran. Electrical Engineering, volume 52, November 1933, pages 758–66.

2. Corona Losses From Conductors of 1.4-Inch Diameter, J. S. Carroll,
(*Concluded on page 244*)

Electrical Water-Level Control and Recording Equipment for Model of Cape Cod Canal

By H. L. HAZEN
ASSOCIATE AIEE

Control of water level according to a predetermined cycle and its automatic recording in a model of the Cape Cod Canal have been accomplished by electrical means which depend for operation upon the capacitances between the surface of the water and metal plates suspended above the water. The theory of operation and the apparatus are described in this paper.

CAPE COD, which extends southeastward approximately 40 miles from the general coast line of Massachusetts, was cut by a canal some years ago to shorten coastwise shipping routes. In connection with the enlargement of this canal to facilitate the passage of large ocean vessels, certain problems arose that made it desirable to study the flow of water in the canal and in the adjoining portions of Cape Cod Bay and Buzzards Bay, using a hydraulic model. These model studies were undertaken as a co-operative project by the department of civil and sanitary engineering of the Massachusetts Institute of Technology, Prof. C. B. Breed in charge, and the Corps of Engineers, U.S. Army, Col. John J. Kingman, district engineer. The experimental work is being done at the River Hydraulic Laboratory at Massachusetts Institute of Technology under the direction of Prof. K. C. Reynolds.

Relatively high velocities of flow occur in the Cape Cod Canal, caused by the fact that the tidal range in Cape Cod Bay is somewhat more than twice that in Buzzards Bay, that is, the tides are more than twice as high, while the relative time phases are such that high water occurs in Buzzards Bay about 3 hours or a quarter-period before it occurs in Cape Cod Bay. In order to study by means of a hydraulic model the effect of enlarging the canal on these velocities, it is evidently necessary to reproduce in miniature the tidal water-level variations in the basins at the ends of the model canal. This requires automatic water-level control equipment. It is also necessary to obtain accurate water-level records at numerous stations along the canal and the adjoining waters of the model, as these readings constitute the useful data.

Both the automatic water-level controllers and the water-level recorders require a means of measuring the average water level over an area of a few square inches. Floats of any sort have proved unsatisfactory for this purpose because of the rather large and uncertain errors introduced by surface tension and by dynamic hydraulic forces. Floats also introduce an uncertain effect on flow in the model. Staff gauge water-level readings are subject to error because of surface waves which are unavoidable in this model. Because of these difficulties the electrical methods described in this paper were developed.

The model, built on a horizontal scale of 1 to 600 and a vertical scale of 1 to 60, represents the 8-mile canal together with $11^1/_2$ square miles of Buzzards Bay at its southern end and one square mile of Cape Cod Bay at its northern end. These areas of bay at either end are sufficient to extend to deep water where the tidal water levels can be assumed to be unaffected by any flow from the canal. By causing the water levels at these 2 deep-water ends of the model to follow any desired tidal cycle, the water levels and flows throughout the model are made to reproduce in miniature and to scale those occurring in nature. In this way the effects that any dredging will have on navigation, or the dredging profiles that are necessary to secure given depths of water, can be predetermined.

The water-level control problem is essentially that of making the water levels at the deep-water ends of the model bay areas rise and fall in accordance with the tides previously observed in nature. This water-level control is accomplished by 2 simultaneous adjustments. The first, or coarse, adjustment is obtained by a time-controlled flow of water into the deep-water end of each basin such that the tidal cycle would be reproduced to a first approximation without additional control. The second, or accurate, water-level adjustment is accomplished by automatically controlling the height of a discharge weir located at the deep-water end of each basin in accordance with the observed instantaneous error in water level near the weir.

In a basin covering a few hundred square feet, the rate of rise or fall of water level can be changed only slowly without causing serious waves. Therefore, a sensitive control device is required which will detect and correct an error in water level before it has become large enough to require a large change in weir discharge. Conversely, a sensitive control is subject to oscillation or hunting unless special care is taken to avoid it. Thus, the problem requires a compromise design based on a quantitative analysis of the dynamics of the entire system involved.

Attention is confined in this paper to the electrical control and recording equipment. The hydraulic aspects of the study are presented in an unpublished report by Prof. K. C. Reynolds.

A paper recommended for publication by the AIEE committee on automatic stations. Manuscript submitted June 15, 1936; released for publication September 3, 1936.

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The author acknowledges the aid others have given in this development; in particular, the enthusiastic co-operation of Prof. K. C. Reynolds, in charge of the River Hydraulic Laboratory at Massachusetts Institute of Technology, and of Prof. R. D. Bennett of the electrical engineering department.

Layout of Water-Level Control System

As stated in the preceding section, the water levels in the 2 basins at the ends of the canal must be continuously adjusted so that the tidal levels observed in nature are correctly reproduced to scale in the model. This is done as follows:

A master "time" unit is used to control the sequence of all model tidal phenomena. This consists of an adjustable-speed d-c motor which is geared to a so-called Selsyn transmitter, and also to a valve-control shaft. The Selsyn transmitter drives 2 Selsyn synchronous motors, one near the weir of each basin. Each of these Selsyn motors is geared to a disk cam. The gearing and Selsyn units are so designed that the valve-control shaft and the 2 disk cams revolve synchronously at a speed of one revolution per tidal cycle. In nature the period of this cycle is about 12.42 hours, which is reduced to 9.63 minutes in the model. Each of the disk cams is essentially a polar plot of the tide-level curve for its basin. The problem then is to make the water level reproduce the tidal data given on the cam.

This is done by means of the apparatus shown schematically in figure 1. The cam continually adjusts the height of the "level unit" through the lever L_1. On this level unit is a plate P. Through the amplifier, weir motor, and rack and pinion, the weir is so controlled by the level unit that the water level tends to remain at a constant distance D from plate P. As the cam is driven by the master time unit, the water level is made to reproduce the tidal curve. Lever L_2 provides damping in a manner explained in detail subsequently.

Evidently if this scheme alone were used to control the water level, enough water would have to be continuously supplied to the basin to raise the level at the most rapid rate called for by the tidal curve and to provide an excess for control by adjustable spillage over the weir. Also the weir would have to have a relatively large maximum spillage to lower the water at the maximum rate and discharge the inflow at the same time. To reduce the inflow of water required, and also to reduce the amount of controlling action imposed upon the weir, the simple expedient of controlling the water input to each basin by valves is used. Adjustable cranks on the valve-control shaft mentioned above operate ordinary gate valves through a lever system. Each gate valve controls the water supplied by gravity to one basin from a central constant-head tank. By suitably adjusting both the stroke and phase angle of these cranks, the amount of water-pump and weir capacity can be greatly reduced and the final level control made much more accurate. A separate valve-controlled water supply and weir-control unit is of course necessary for each of the 2 basins.

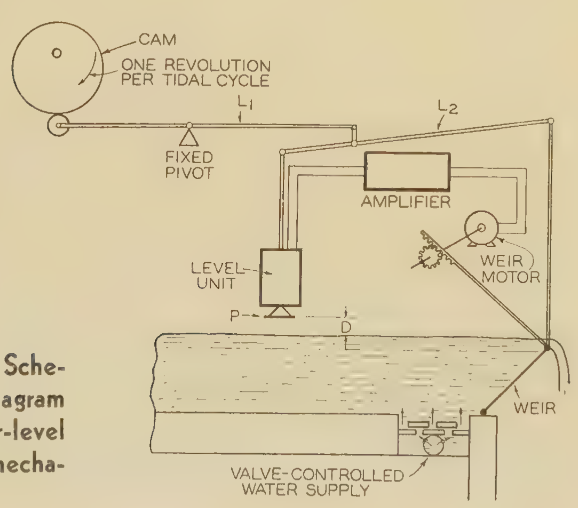


Fig. 1. Schematic diagram of water-level control mechanism

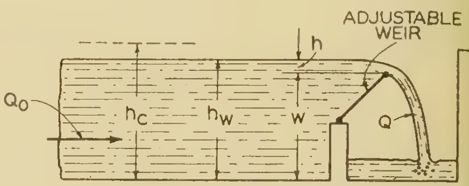


Fig. 2. Diagram of a portion of a basin showing dimensions used in the analysis

In the following section an analysis of the dynamic behavior of this water-level control system developed for the purpose of designing a stable and sufficiently accurate system is given.

Analysis of Control System

Figure 2 shows schematically a portion of a basin representing the bay at one end of the canal for the purpose of indicating some of the hydraulic dimensions used in the control analysis. Three components of water flow affect the water level in this basin: first, the flow in and out from the canal; second, the flow in from the constant-head tank, controlled by the crank-operated gate valve; and third, the flow out over the weir. When the algebraic sum of these 3 components is correctly adjusted the water level in the basin will follow the prescribed tide-level curve. The first component is not subject to arbitrary control. The second component is an adjustable periodic function of time. Preliminary analysis showed that it should be such a function of time that the third component or weir discharge is approximately constant. This third component is then adjusted from instant to instant by the automatic control of the weir height to reduce the residual error in water level to a negligible value.

The analysis that follows applies to the action of the automatic weir-height control device. Let

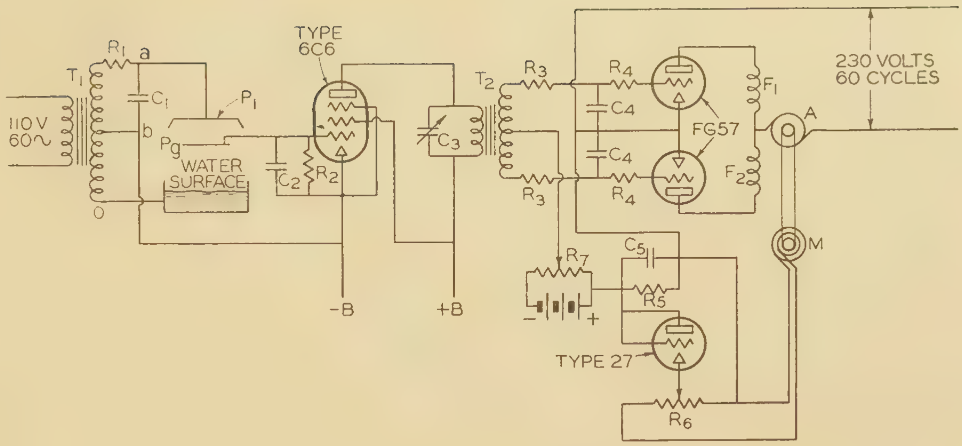
h_c = desired height of water at any instant (feet)
h_w = actual height of water at any instant (feet)
w = height of weir crest (feet)
t = time (seconds)
Q_o = net inflow to basin including flow from pump and canal (cubic feet per second)
Q = weir discharge under head h (cubic feet per second)
h = head on weir (feet) = $h_w - w$
h_o = average value of h (a constant)
l = length of weir (feet)
A = area of basin (square feet)

All heights are measured from an arbitrary datum plane.

Two equations describe the motion of the system.

ig. 3. **Water-level controller circuit**

$_1$ = 0.01 microfarad
= 4,000 ohms
$_2$ = 0.0001 microfarad
= 30 megohms
$_3$ = 0.17 microfarad
= 1.0 megohm
$_4$ = 0.003 microfarad
= 50,000 ohms
$_5$ = 1.05 microfarad
= 50,000 ohms
= 1,500 ohms
= Audio transformer (Sampson type Y)



he first is the water-level equation

$$\frac{h_w}{lt} = \frac{Q_o - Q}{A} \tag{1}$$

he second equation describes the control action exerted n the weir, which can be arbitrarily specified. Prelimiary analysis indicated that this control system would perate properly if the weir speed were made to depend nearly on the sum of 2 quantities, the error in water evel, and the departure of the head on the weir from its verage value. The weir-height equation is then

$$w \; = g(h_c - h_w) + m(h_w - w - h_o) \tag{2}$$

n which g and m are constants. The right-hand term in quation 2 introduces required damping, as shown subseuently. The coefficients g and m are to be fixed by the iven allowable error and the necessity for aperiodic peration.

Before combining equations 1 and 2, Q must be exressed in terms of the head on the weir. The law assumed or the weir discharge was

$$= 3.33\, lh^{3/2} \tag{3}$$

hich can be put into an approximate linear form in $h - h_o$) for heads near an average head h_o by using the rst 2 terms of a Taylor's expansion about h_o. Thus

$$= 3.33\, lh_o^{3/2} + 5.00\, lh_o^{1/2}(h - h_o)$$

ithin about 5 per cent for $0.7\, h_o < h < 1.5\, h_o$. Substiuting this approximation in the right-hand term of quation 1 gives

$$\frac{{}_o - Q}{A} \approx q_o - q_1(h_w - w - h_o) \tag{4}$$

n which

$$= \frac{Q_o - 3.33\, lh_o^{3/2}}{A} \tag{5}$$

nd

$$= 5.00 \frac{l}{A} \sqrt{h_o}$$

$$= 5.00 \frac{l}{A} \sqrt[3]{\frac{Q_{ave}}{3.33\, l}} = \text{constant} \tag{6}$$

From equation 6 it may be seen that the average weir discharge Q_{ave} fixes the constants h_o and q_1. It also fixes the constant term of q_o.

Putting equation 4 in equation 1,

$$\frac{dh_w}{dt} = q_o - q_1(h_w - w - h_o) \tag{7}$$

Differentiating equation 7 with respect to time, substituting equation 2 in the result, writing p for $\frac{d}{dt}$, and rearranging gives

$$p^2h_w + q_1ph_w + mph_w + q_1gh_w - q_1gh_c - p\,q_o - mq_o = 0 \tag{8}$$

Since the error in water level is desired rather than the

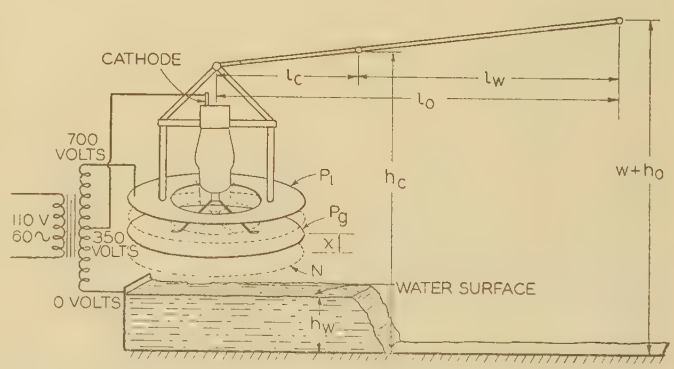


Fig. 4. Diagram of damping lever

N indicates position of P_g for zero alternating potential on grid of tube

actual height of water, equation 8 is rewritten using a change of variable

$$\delta = h_c - h_w \tag{9}$$

in which δ = error in water level in feet. Putting equation 9 in equation 8 and solving for δ gives

$$\delta = \frac{(p + q_1 + m)ph_c - (q + m)q_o}{p^2 + (q_1 + m)p + q_1g} \tag{10}$$

In equation 10, h_c and q_o are time functions that can be determined from the tidal-level data, the valve-crank

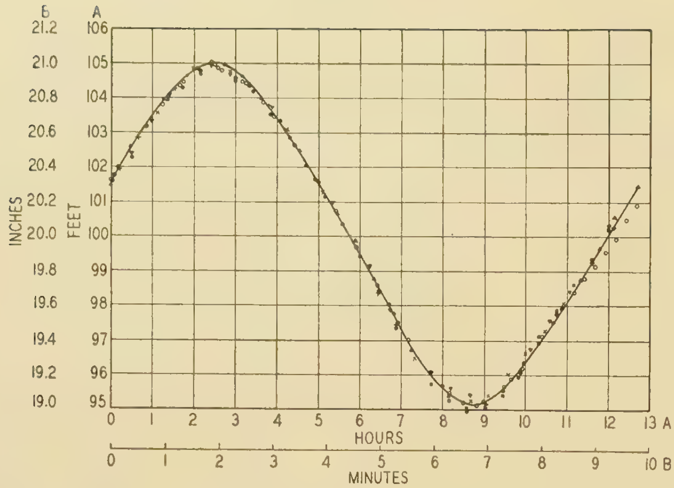


Fig. 5. Typical level-controller performance

Scales *A* for nature; scales *B* for model

Circles are actual tidal data obtained at Cape Cod Bay approach to canal. Solid curve is idealization of these data for model tide cycle. Other plotted points are typical water-level records taken in course of model studies

adjustments, and the dimensions of the basins; q_1 is a constant fixed by the constant component of weir spillage due to the average weir head h_o.

In order to determine m and g, 2 additional conditions need to be imposed. The conditions selected are, first, that the operation must be aperiodic, and second, that the maximum value of the error δ shall not exceed a prescribed amount. For critical aperiodic operation, the denominator of equation 10 must have equal real roots, which imposes the condition

$$(q_1 + m)^2 = 4q_1g \tag{11}$$

The error condition is next imposed. A consideration of various features of the model study led to the selection of 0.0010 foot (equivalent to 0.06 foot in nature) as the maximum permissible value of δ which, preliminary calculations indicated, could be attained with reasonable apparatus.

It is subsequently shown that $q_1 << m$ and that therefore the numerator of equation 10 can be written with sufficient accuracy as

$$(p + m)(ph_c - q_o) \tag{12}$$

But $ph_c - q_o$ is the residual flow per unit of basin area which the automatic control must correct by adjustment of the weir, and can therefore be approximately described as a known function of time for either basin.

Thus far the analysis has been general, that is, it applies to any system of the type described. At this point it is desirable to insert actual numerical values, which necessitates considering a specific case. The end representing Buzzards Bay is arbitrarily chosen for the numerical work that follows.

Examination of the expected flow relations in the model of Buzzards Bay shows that this residual flow will impose on the automatic control a condition no more severe than that imposed by a sine-wave flow having an amplitude of 0.20 cubic foot per second and a period one-third that of the main tidal cycle. The main tidal period in the model is approximately 9.6 minutes. Therefore, for the basin of 900 square feet area the residual level variation to be corrected can be assumed for the purpose of design to have the form

$$ph_c - q_o = \Delta \sin 3 \frac{2\pi}{T} t \tag{13}$$

in which

T = the period of the tidal cycle in model (seconds)

Δ = amplitude of assumed residual level error to be corrected by automatic control (feet)

Putting in the above numerical values,

$$ph_c - q_o = \frac{0.20}{900} \sin 3 \frac{2\pi}{9.6 \times 60} t$$

$$= 2.22 \times 10^{-4} \sin 0.0327t.$$

Replacing p in equation 10 by $j\omega_3$ where ω_3 is the angular velocity of the assumed residual level variation and $j = \sqrt{-1}$, and remembering that $q_1 << m$, gives

$$\frac{\delta}{\Delta} = \frac{m + j\omega_3}{-\omega_3^2 + mj\omega_3 + q_1g} \tag{14}$$

Using the simplified condition for critical damping

$$q_1g = \frac{m^2}{4} \tag{15}$$

in equation 14 gives

$$\frac{\delta}{\Delta} = \frac{m + j\omega_3}{\left(\frac{m}{2} + j\omega_3\right)^2} \tag{16}$$

Trial shows that $\omega_3 << m$, when equation 16 becomes

$$\frac{\delta}{\Delta} = \frac{4}{m}$$

Putting in numerical values gives

$$m = \frac{4 \times 2.22 \times 10^{-4}}{0.0010} = 0.89$$ foot of weir height per second for one foot departure of the weir head from h_o

The quantity q_1 must now be evaluated. The average weir discharge for the conditions under which the auto-

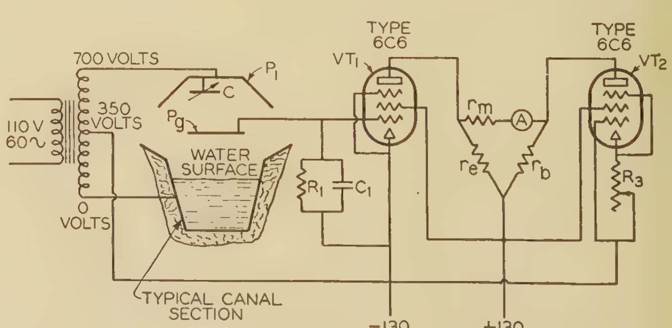


Fig. 6. Circuit diagram of water-level recorder

R_1 = 30 megohms C_1 = 0.0001 microfarad

R_3, r_m, r_l, and r_b vary from unit to unit

matic control is to work is 0.7 cubic foot per second, which gives a value for the weir 12 feet long of

$$q_1 = \frac{5 \times 12}{900} \sqrt[3]{\frac{0.7}{3.33 \times 12}} = 0.0174 \text{ (dimensions same as for } m\text{)}$$

The assumptions $\omega_3 << m$ and $q_1 << m$ can now be checked. Thus

$\omega_3 = 0.0327$
$q_1 = 0.0174$
$m = 0.89$

which shows them to be justified within the accuracy justified by other data.

The constant g can now be calculated from equation 15.

$$g = \frac{m^2}{4q_1} = \frac{0.89^2}{4 \times 0.0174} = 11.4 \text{ feet of weir height per second for one foot error in water level}$$

This completes the dynamic analysis, as all parameters are fixed.

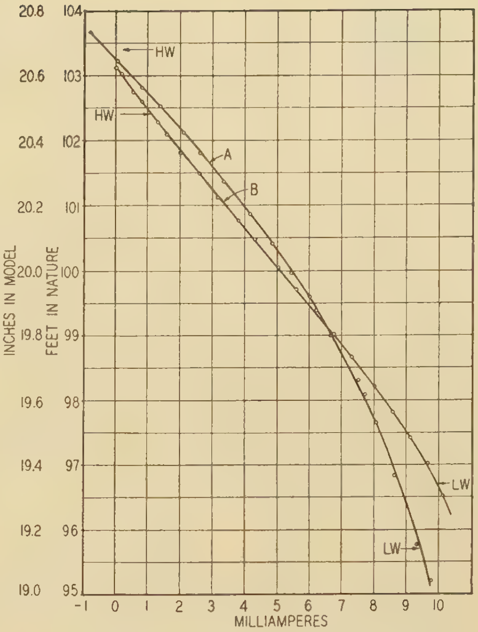


Fig. 7. Typical calibration curves for water-level recorder

LW—Low water

HW—High water

A—Recorder at narrow channel section adjacent to bridge piers

B—Recorder away from disturbing structures extending above water

Design of Apparatus

Having determined the necessary numerical values of the damping coefficient m and the level-restoring coefficient g, which are the 2 important dynamic parameters, the problem shifts to the design of apparatus that will be characterized by these values. This apparatus includes 3 essential parts: first, a level-measuring device; second, an amplifying device and motor to furnish power to operate the weir in accordance with the indications of the level indicator; and third, a suitable mechanism for inserting the damping described by the coefficient m. These parts will be described in order.

Figure 3 shows schematically the electrical features of the level indicator, amplifier, and weir-driving motor. The level indicator is essentially an electrostatic potential divider consisting of the water surface and the plate P_1 as its terminals between which the plate P_g picks up electrostatically a potential intermediate between that of P_1 and the water. Plate P_1 is maintained at a 60-cycle alternating potential of 700 volts, effective value, above the potential of the water by the transformer T_1. The grid-to-cathode voltage of a type 6C6 pentode is the difference between the potential of plate P_g and the midpoint of the 700-volt winding of T_1. The plates P_1 and P_g are fixed mechanically with respect to each other and are moved as a unit by the water-level cam previously described. At some water level, P_g and the midtap of T_1 will be at the same potential, and hence the grid-to-cathode voltage will be zero. If the water level is above this balance level, the grid will have impressed on it a 60-cycle voltage of a certain phase. If the level is below, the phase of the grid voltage will be displaced 180 degrees. Parts R_1 and C_1 constitute a phase-correcting circuit for making the voltage between a and b precisely in phase with the voltage between b and o. This is required because the 2 secondary halves of T_1 are differently loaded.

Although the capacitance between P_g and P_1 or P_g and the water is only about 20 micromicrofarads, the circuit is very stable and requires practically no shielding. This is due in part to the excellent insulation of P_g, obtained by mounting it directly on the grid cap of the tube.

The amplifier consists of a type 6C6 pentode and 2 type FG57 thyratrons. The thyratrons are so biased by means of the resistance drop in R_7 that they fail to fire when no alternating current is present in the plate current of the pentode. Both have the same plate voltage but the a-c components of their grid voltages differ in phase by 180 degrees. The circuits are so adjusted by C_3, R_3, and C_4 that their grid and plate voltages are either in phase or 180 degrees out of phase. Consequently when the water level is above or below balance level, one or the other of the thyratrons fires, taking current from the 230-volt 60-cycle supply through the d-c motor armature A and one motor field F_1 or F_2, thus driving the motor in one direction. To maintain correct phase relations this 230-volt supply must necessarily come from the same feeders as the 110-volt supply for T_1. If the other thyratron is fired, current flows through the motor armature and the other field, driving the motor in the opposite direction. The motor drives the hinged weir through a reduction gear and rack and pinion, as indicated in figure 1. Of course connections must be so made that a low water level raises the weir, and vice versa.

One other feature of the circuit will be mentioned. The motor (and weir) speed should be proportional to the indicated error in water level. The alternating voltage on the thyratron grids is proportional to this error. But the thyratrons are "on" and "off," that is, not smooth-control devices when used in this way. However, by driving an a-c magneto M by the motor, rectifying its output, and charging capacitor C_5, which is shunted by a leak R_5, an additional d-c bias can be applied to the thyratrons. If this additional bias exceeds the peak value of the a-c grid voltage, it will cause the previously-firing tube to cease firing until the motor speed has de-

creased. Thus the average motor speed is kept very nearly proportional to the indicated error in water level.

Thus far no mention has been made of introducing damping. This important aspect will now be considered. Equation 2 can be written

$$\frac{dw}{dt} = (g - m)\left[\frac{g}{g - m} h_c - h_w - \frac{m}{g - m}(w + h_o)\right] \quad (17)$$

in which the weir speed $(dw)/(dt)$ is a linear function of 3 heights—the desired water height h_c, the actual water height h_w, and the weir-crest height w, h_o being a constant. This suggests the linkage shown in figure 4. The weir speed is proportional to the distance x, if x is small, by which the plate system P_1P_g is removed from its zero indication position, that is

$$\frac{dw}{dt} = kx$$

Since the water height is a directly additive (with negative sign) component in x, evidently $k = g - m$ and

$$x = \frac{g}{g - m} h_c - h_w - \frac{m}{g - m}(w + h_o) \quad (18)$$

or

$$x + h_w = \frac{g}{g - m} h_c - \frac{m}{g - m}(w + h_o) \quad (18a)$$

The linkage of figure 4 will produce this result if

$$\frac{l_o}{l_w} = \frac{g}{g - m}$$

Putting in the numerical values for the design for Buzzards Bay gives

$$\frac{l_o}{l_w} = \frac{11.4}{11.4 - 0.89} = 1.085$$

or

$$l_w = \frac{l_o}{1.085} = 0.92\, l_o$$

As mentioned earlier in the paper, all heights are measured from any common datum plane.

Final experimental adjustments of the constant g were made by gear ratios and the values of R_5 and C_5 (see figure 3).

A similar calculation was made for the Cape Cod Bay basin controller which need not be repeated here, since it merely involves different numerical values.

Practical Considerations

In the theoretical design given above, certain idealizations were made that are not realized in practice. One of the most serious of these is the tacit assumption that the water level changes at the same rate over the entire basin, following an adjustment of the weir height. Actually this is not so for 2 reasons. The first is that the weir displaces water when it is moved. This sets up a wave of higher or lower level, depending on whether the weir is raised or lowered, that propagates away from the weir over the basin at a finite rate. The second reason is a lowering or raising of the weir also produces a lowering or raising of the water level due to a cha discharge rate. This level change also propagates finite velocity.

If the water-level indicator for the controller is not close to the weir, there is an appreciable time lag betw the change in water level at the weir and the chang level at the level indicator. Such time delays in ge

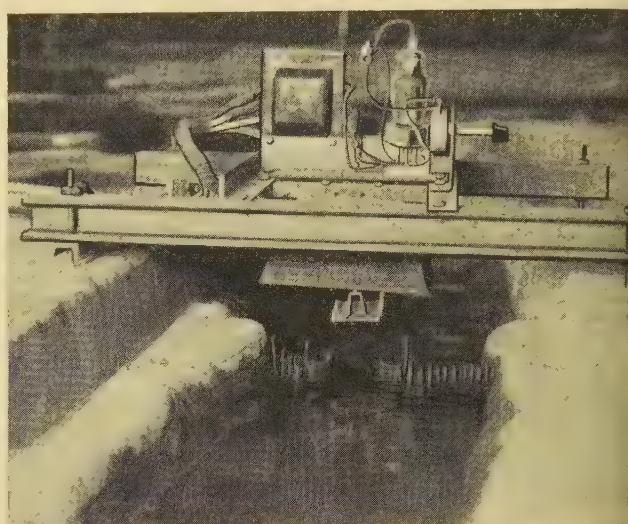


Fig. 8. Level-recorder unit in place over canal

Plate P_g (figure 6) appears immediately above "bridge piers" in canal. Plate P_1 is the hood immediately above P_g. Tube VT_2 and resistor R_3 appear above framework

have the effect of introducing negative damping into control system, that is, they tend to set up oscillat In this installation this time lag was appreciable, w necessitated introducing somewhat more damping t that called for by the analysis. Final adjustment of damping was made experimentally under actual opera conditions.

In the analysis it was assumed that the residual flo be controlled by the automatic controller was made s by carefully adjusting the gate-valve cranks. In ac operation it proved more expedient to adjust these cra only approximately and to make final adjustment of tidal cycle by filing the control cams to a shape slig different from the actual tidal curve. Since each t cycle is given a considerable amount of study, the t required to adjust the cams for each new cycle by fili relatively unimportant. The advantage of making adjustment by filing the cams is that there is a much r direct and easily-visualized relation between the resi water-level error and the change in the cam necessar correct it than there is between this error and the co sponding corrective change in valve-crank setting. the cams are corrected, the tidal cycle repeats accura thereafter, independent of any minor changes in the c flow caused by trial modifications of the model.

Controller Performance

After the adjustments described, together with certain ninor circuit adjustments, were made, the controllers vere put into operation in November 1935, and they have operated consistently since then with little attention. Errors in the water level of the 2 basins have been within he limits established as satisfactory for the studies to be nade. Rough tests were made of the dynamic per-ormance of the controller which showed that the device was operating in substantial accord with the design calcu-ations. The significant test, however, is the performance of the controllers in accurately controlling the water evels under actual operating conditions. Typical per-ormance data are shown in figure 5. In this figure the ircles represent actual tidal data recorded at the Cape Cod Bay approach to the canal. The solid line is the lightly-idealized tidal cycle derived from these data to be reproduced in the model. The remaining plotted points are those obtained on the model during a series of ypical runs.

Water-Level Recorder

Attention is now turned to the other apparatus used on the canal model which is of interest to electrical engi-neers, namely, the water-level recorders.

As in the case of the water-level indicator for the water-evel controller, floats were barred for level recorders because of the serious and uncertain errors introduced by urface tension and by dynamic forces caused by water urrents. The general scheme adopted for the water-evel recorder is similar to that described hereinbefore, hat is, the water surface is used as one electrode of an lectrostatic potential divider from which the grid poten-ial of a pentode is derived. In the recorder, however, he variation in the d-c component of plate current rather han in the a-c component is used to indicate the water evel. This d-c component is indicated by a d-c milli-mmeter. The simultaneous recording of the indications or the 9 water-level stations in the model is done photo-raphically.

In figure 6 is shown the circuit of a recorder. The chief lifference between this circuit and that of the first tube in igure 3 is the method of utilizing the output. In the ecorder circuit, the fixed plates P_1 and P_g are so placed, nd the adjustable plate C so set, that at the lowest vater level the capacitance between the water and P_g is lightly greater than that between P_g and P_1, thus im-pressing sufficient alternating voltage on the grid to reduce he plate direct current slightly (about 10 per cent) below ts value for equal capacitances. As the water level is aised, the capacitance unbalance and hence the grid lternating voltage become greater, decreasing the plate irect current. Thus the plate direct current is a measure f the water level. This is the general scheme of opera-ion.

A number of refinements are necessary to reduce the rrors. The goal for error was set at 0.5 millimeter robable error for level ranges up to about 4.5 centi-meters. Plate P_g is 2.5 centimeters or more from the high-water level to avoid difficulties resulting from splash-ing, while the canal section in some cases is only about 13 centimeters wide at the top. These conditions made it difficult to reach the desired accuracy with simple equipment.

Proper shaping and placing of plates P_1 and P_g are important in order to obtain adequate sensitivity at low water when the capacitance of P_g to the canal walls is much larger than its capacitance to the water surface, and when the rate of change of the latter capacitance with respect to water level is small. Conversely, at high water the rate of change of this capacitance with water level is relatively high. A reasonably linear calibration curve was obtained by using the steepest part of the curve for grid alternating voltage versus plate direct current at low water, and the flatter part at high water. Typical calibration curves are shown in figure 7. Because some grid alternating voltage is necessary even at low water, no phase-correcting circuit was required on the 350–700-volt half of the a-c high-voltage supply for a level-recorder unit.

Another aspect that must be given careful attention is the error resulting from variations in screen voltage. Unless some form of compensation is used, this error can easily become as much as 2 or 3 millimeters of water level per volt change in screen voltage at 130 volts for the 6C6 tubes used. By using a second 6C6 tube VT_2 with fixed

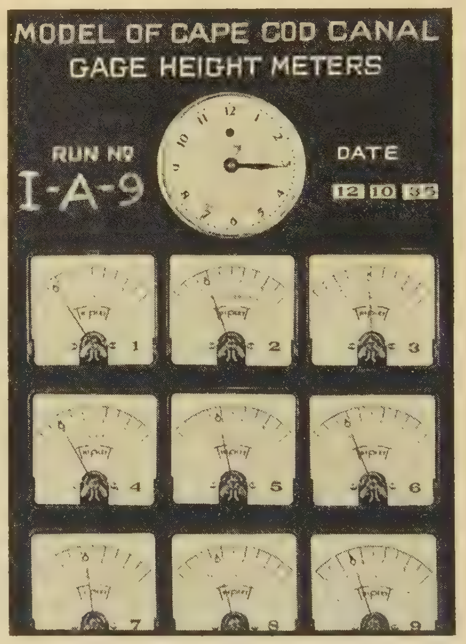


Fig. 9. Instrument panel for water-level recorder

The 9 milliammeters indicate water levels at 9 stations in model. Water levels are obtained from calibration curves

grid voltage (see figure 6), this sensitivity to changes in screen voltage is considerably reduced and at the same time a convenient means is provided for suppressing the zero of the d-c plate milliammeter A. The screens and heaters of both tubes are supplied from the same sources. By suitably adjusting the values of the resistances r_m, r_l, and r_b in the milliammeter mesh, the milliammeter reading can be made to range over any desired fraction of

full scale for any given range of water-level variation. By adjusting the resistance R_3, these readings can be centered on the meter scale. The resistance r_m is made large enough so that the temperature error due to copper in the milliammeter is made negligible. This feature is pertinent because of the rather wide fluctuations in temperature occurring in the building in which the model is located.

The best shape of calibration curve for water level versus milliammeter reading is obtained by properly shaping and placing the P_1 and P_g plates, and finally by adjusting the low-water grid alternating voltage with the small auxiliary capacitor plate C.

Both alternating and continuous voltage regulators are used in the power-supply circuits because of the high degree of consistency required of the tubes and circuits. By this means the cathode temperature, the grid alternating voltage, and the screen voltages are maintained within the necessary close limits.

Figure 8 is a view of an assembled level-recorder unit in place over a section of the model canal. The instrument panel containing the 9 milliammeters, a clock, and a place for data pertaining to a run is shown in figure 9. This is photographed at intervals of 20 seconds throughout a tidal cycle lasting 9.63 minutes by means of a 35-millimeter motion-picture camera. After the film is developed the meters and clock are read from the projected image of the negative. Figure 9, in fact, is reproduced from one of the photographs taken in routine recording.

Performance of Water-Level Recorder

The recorders have been in operation practically continuously since November 1935. With them level measurements have been consistently obtained that utilize the full hydraulic accuracy of the model.

In general the uncertainty of a current reading has been found to be of the order of 0.005 milliampere in a recorder-current range of about 0.8 milliampere. In terms of water level this represents an uncertainty of from 0.12 to 0.25 millimeter. Using the vertical scale factor of 1 to 60 between model and nature, this uncertainty is seen to represent from about 0.025 to 0.05 foot in nature, the larger figure being associated with the larger tidal ranges.

To achieve this precision requires careful calibration at intervals of 2 or 3 weeks. Other operating precautions are also necessary, such as careful control of all voltages, and allowing a warming-up period of about half an hour previous to taking readings. As stated hereinbefore, both alternating and continuous voltages are automatically controlled by voltage regulators whose settings are checked by manual adjustment. Good-grade portable voltmeters have sufficient accuracy for use in this checking and adjustment.

The principal cause for frequent calibration is the gradual change in the mutual conductance of tubes with use. Because of this change it is occasionally necessary to readjust the resistance r_m, shown in figure 6, in order to maintain a working range of 0.8 to 0.9 of full scale on the meter for the working range of water level. This is done before a calibration and occasions little inconvenience.

Summary

The electrical equipment described in this paper has made possible the successful reproduction of tidal cycles and accurate recording of water levels in a hydraulic model. The equipment is relatively simple and inexpensive. Although requiring some care in operation, it has proved entirely serviceable and has been in practically continuous use since the installation was completed in November 1935. Ordinary adjustments are made by engineers with little electrical training. The results obtained with this electrical equipment are sufficiently accurate to make the hydraulic errors the controlling factor in the over-all accuracy of the model studies.

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Lightning Currents in 132-Kv Lines

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Data pertaining to lightning currents actually measured in tower structures, counterpoises, and ground wires on 132-kv lines during 1933–36 are presented in this paper. It is concluded that stroke currents rarely exceed 150,000 amperes, although 220,000 amperes has been indicated, and that currents as high as 60,000 amperes measured in the overhead ground wires indicate the necessity of adequate shielding of the line at station entrances.

THE organized field and laboratory investigations on the effects of lightning on electric systems and apparatus, started some 10 years ago, have uncovered many of the mysteries of lightning affecting line performance and equipment protection. Voltage magnitudes and polarity have been measured, wave shapes determined with some degree of completeness and certainty, and frequency and severity of lightning disturbances observed.

As various theories of the mechanism by which lightning produced its disturbing effect on electric systems were put forth, discussed, and checked against the field operating experience, it became apparent that a fuller knowledge of the currents in the lightning stroke itself, and their distribution in the various parts of the electric system subject to its influence, were urgently needed to help solve the problems of lightning protection to lines and equipment.

Having actively entered into the very early investigation work mentioned above, and having recognized the value of this work in bringing about better service to electricity consumers and greater protection to apparatus, the authors have continued without interruption the field investigation work first started some 10 years ago. However, during the past 4 years their research has centered about the problem of determining lightning currents in strokes themselves, and in various parts of the transmission network. This investigation has been conducted on the properties of the American Gas and Electric Company and in co-operation with the General Electric Company.

In this paper there will be presented in a summarized form the high points of the field data obtained during the period 1933 to 1936, inclusive. Particular emphasis will be laid on the lightning currents actually measured in lightning strokes, tower structures, counterpoise wires, and ground wires. Correlation of line performance with these data will be given to the extent warranted by the data. However, the authors believe that, in view of the large volume of field data secured in this investigation of the past 4 years, it will be best to use available space to present the maximum amount of pertinent data, interpreting and correlating only the most important parts of those data.

The investigation was carried out on 2 132-kv lines forming part of the American Gas and Electric Company network, and on one line constructed for 132-kv but operated at 66-kv. These lines are the Glenlyn-Roanoke in Virginia, Philo-Canton in Ohio, and Deepwater-Pleasantville in New Jersey, respectively. Their general design characteristics and past performance record have been previously presented.[1] The major part of the field measurements was obtained on the Glenlyn-Roanoke line where instruments were located to record lightning currents in tower structures, tower arms, counterpoise wires, ground wires, and tower-top lightning rods. The impulse flashover characteristics of insulator assemblies on this line are approximately 910 and 750 kv on the 1x5 and $1^1/_2$x40 impulse waves, respectively. On the Philo-Canton and Deepwater-Pleasantville lines, measurements were recorded in tower-top lightning rods only.

To make most effective use of the available equipment, measuring instruments were concentrated at line locations which from past experience appeared to be the most heavily lightning-infested sections of the line. The degree of instrument coverage in per cent of total line length on which investigation was carried out throughout the 4 years (1933 to 1936) was 7.3 per cent of the Philo-Canton line, 5.3 per cent of the Deepwater-Pleasantville line, and 100 per cent of the Glenlyn-Roanoke line in 1933–34 and 1935, and 23 per cent in 1936. Summarizing this on the basis that would have existed if the entire work had been carried out in one year, the field setup to record lightning currents appears as follows:

	Length of Line Investigated (Miles)
Tower-top lightning rods	70
Counterpoises	28
Tower arms	88
Tower legs	218
Ground wires	29

In evaluating the extent of line covered as shown by the above tabulation, it must be remembered the 4-years' work gave a diversity of lightning severity not possible with a single-year's investigation.

Determination of Lightning Currents

All lightning currents reported here were determined by the surge-crest ammeter in the field. The surge-crest

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1. For all numbered references see list at end of paper.

ammeter[2] consists essentially of small laminated cobalt-iron magnets approximately $1^1/_2$ inches long by 0.1 square inch in cross section placed in a definite position in the magnetic field of the conductor in which the current is to be measured. By measuring the residual magnetism left in the magnet after the passage of current the crest value of the current is determined and in some cases its oscillatory characteristics as well.

The field setup of these magnetic links on a typical tower as installed in 1936 is shown in figure 1. Similar installations were in service during 1933, 1934, and 1935, although all towers at which field setups were made did not provide for measurements at all points of the tower structure shown in figure 1.

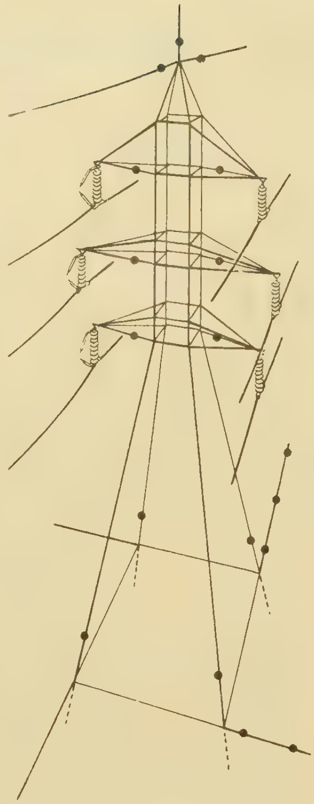

Fig. 1. Arrangement of magnetic links of surge-crest ammeter on a typical tower in 1936

The number of surge link installations and their locations for the 4 years herewith reported are shown in table I. Previous to 1936 currents were measured in quite a few towers by the use of one surge link installation on one leg only of the tower, the total tower current being subsequently obtained by multiplying the reading recorded in one leg by 4. Although this method of measurement seemed to give reasonably accurate results, the more precise method of using separate link installations on each tower leg was followed in 1936 when the investigation was concentrated on particularly heavy lightning infested line sections.

In the attempt to determine the flow of lightning current in the tower structure, several cases were encountered in the past where the absence of any current indication in certain locations caused some doubt as to the interpretation to be placed on the results. In such cases it is necessary to consider both the maximum and minimum currents the surge-crest ammeter, as set up, is capable of measuring. The range of measurements for the different types of field installations is shown in table II, these values being for unidirectional surges. Currents of the oscillatory type can be measured in a slightly higher range by suitable calibration of the surge-crest ammeter. This was done in some cases.

Field Measurements of Current

Although the field records are too numerous to present completely here, some of the outstanding data and a summary will be given for currents measured in tower legs, tower-top lightning rods, tower arms, counterpoises, and ground wires, and the 4-years' data condensed and correlated so far as space permits.

A knowledge of lightning currents, both in the stroke itself and in the tower structures, was early recognized as most valuable as an aid to the study of lightning performance of lines. Therefore, the field setup was planned to obtain current readings in the lightning stroke by various means and in the tower structures by measurements in the tower legs close to the ground line.

Currents in Tower Legs and Lightning Stroke

A summary of currents obtained in legs on single towers for the 4 years is given in table III. It may be observed that over 150 observations of currents in excess of 10,000 amperes, 14 in excess of 50,000 amperes, and 2 between 90,000 and 100,000 amperes were made. Such data have been used in the past in combination with individual tower-footing resistances to indicate the maximum potential of the tower, and from that the possibility of flashover under lightning conditions has been predicted and in many cases verified.

In determining the lightning current in the stroke itself, 3 different methods of attack have been used. The first consisted of a summation of lightning currents in

Table I—Number and Location of Surge-Crest Ammeters

Location	1933	1934	1935	1936	Total
Glenlyn-Roanoke Line					
All 4 tower legs	240	560	560	368	1,728
One tower leg only	212	132	132	3	479
One per crossarm	270	270	450	450	1,440
One per counterpoise	0	80	40	0	120
Two per counterpoise	0	0	0	40	40
Three per counterpoise	0	0	40	40	80
Two per ground wire*	0	0	80	120	200
Tower-top lightning rod†	20	20	20	0	60
Tower-top lightning rod‡	20	20	20	20	80
Philo-Canton Line					
Tower-top lightning rod	30	30	30	30	120
Deepwater-Pleasantville Line					
Tower-top lightning rod	30	30	30	30	120
Totals	822	1,142	1,402	1,101	4,467

* One on each side of tower.
† Lightning stroke recorder across resistor.
‡ Surge-crest ammeters; at same location as lightning stroke recorders 1933–34–35.

Table II—Application and Range of Measuring Instruments

Location	Magnet Spacing From Conductor Centers—Inches: Inner	Outer	Unidirectional Current Range—Amperes: Minimum	Maximum
Tower arms	2.6	2.6	1,600*	16,000*
Counterpoises	1.25	4.0	800	25,000
Ground wires	3.5	12.0	2,000	73,000
Tower legs, 6-inch	3.35	9.35	2,000†	57,000†
Tower legs, 8-inch	4.1	10.1	2,500†	61,000†
Lightning rods	4.0	4.0	2,500	25,000
Lightning rods	3.5	12.0	2,000	73,000

* One arm member only; multiply by 2 for total arm current.
† Measurements on one leg.

adjacent towers which appeared to be affected by one lightning disturbance. A summary of these data for the 4 years is shown in table IV. Here 31 stroke currents in excess of 50,000 amperes, 12 in excess of 100,000 amperes, and a maximum of 220,000 amperes for the stroke are indicated. The second method of determining current in the lightning stroke was by direct measurement in the tower-top lightning rod mounted at the tower top with suitable measuring instruments. Here the current in the stroke is measured directly. Data for the 4 years obtained in this way are shown in table V. The currents by this method of determination run much lower, the maximum current recorded being 50,000 amperes. The third and partially direct method, although not carrying with it the certainty of the direct measurement in the lightning rod but still probably having more justification than the addition of currents in the adjacent tower legs, is the method of adding current readings in a ground wire section as recorded at adjacent towers under conditions where the lightning stroke appears to have hit the ground wire in mid-span and has flowed in both directions to adjacent towers. Adding these currents at each end of the affected spans gives a value of the total lightning-stroke current. These data are given in table VI. These in a single year's observation on one line show 7 records in excess of 50,000 amperes and 1 in excess of 100,000 amperes, the maximum being 110,000 amperes. The stroke currents obtained by each of these 3 methods have been plotted in curve form in figure 2. A curve representing the average of these 3 methods of determining stroke current has been plotted here also and another showing the single tower currents tabulated in table III. It is particularly interesting to compare the last curve with the curve of average total stroke current.

Table III—Tower Currents Above 5,000 Amperes per Tower

Number of Tower Years 911

Amperes	1933	1934	1935	1936	Total
5,000– 10,000	12	15	16	18	61
10,000– 20,000	12	24	11	15	62
20,000– 30,000	4	16	8	14	42
30,000– 40,000	1	26	11	7	45
40,000– 50,000	0	7	2	2	11
50,000– 60,000	1	2	1	2	6
60,000– 70,000	1	3	0	0	4
70,000– 80,000	0	0	1	1	2
80,000– 90,000	0	0	0	0	0
90,000–100,000	0	2	0	0	2
Total	31	95	50	59	235

Table IV—Lightning-Stroke Currents Indicated by Summation of Tower-Leg Currents

Number of Tower Years 911

Kiloamperes	1933	1934	1935	1936	Total
10– 20	12	3	3	6	24
20– 30	2	10	4	10	26
30– 40	1	11	2	4	18
40– 50	1	7	4	2	14
50– 60	0	1	1	3	5
60– 70	1	0	2	0	3
70– 80	0	3	0	3	6
80– 90	0	2	1	0	3
90–100	0	1	0	1	2
100–120	1	2	2	1	6
120–140	0	3	1	0	4
140–160	0	0	0	0	0
160–180	0	0	0	1	1
180–200	0	0	0	0	0
200–220	0	1	0	0	1
Total	18	44	20	31	113

Table V—Lightning-Stroke Currents by Direct Measurement in Tower-Top Lightning Rods

Number of Tower Years 380

Kiloamperes	1933	1934	1935	1936	Total
5–10		0	0	0	0
10 20		8	11	6	25
20–30		1	0	2	3
30–40		0	0	2	2
40–50		0	0	4	4
Total		9	11	14	34

Table VI—Lightning-Stroke Currents by Addition of Ground-Wire Currents; Glenlyn-Roanoke Line, 1936

Amperes	Number of Records
10,000– 20,000	2
20,000– 40,000	11
40,000– 50,000	5
50,000– 60,000	1
60,000– 70,000	4
70,000– 80,000	1
100,000–110,000	1
110,000 maximum	

Lightning Currents in Counterpoises

The indicated benefits of counterpoises both by theory and, to some extent, by practice has led to a search for actual field data to show what was taking place in these buried conductors under lightning conditions. Field setups were therefore made to measure currents at various points along the counterpoise length. The particular counterpoises used on the Glenlyn-Roanoke line consisted of 2 long (150 feet) buried wires parallel to the line and 2 40-foot buried wires at right angles to the line. Current measurements on the long counterpoise were made on both ends and in the middle, and on the short counterpoise at both ends (see figure 1). The current distribution in these counterpoises is shown in figure 3, in percentage of the current measured in the long counterpoise at the point close to where connected to the tower. Figure 3 shows that the long counterpoise carries on the average approximately 4 times as much current as the short counterpoise as measured at the tower leg. At a distance of 40 feet which, in this case, is the end of the short counterpoise, the long counterpoise is carrying 6 times the current measured in the short counterpoise. It will also be noted that the current on the end of the short counterpoise is approximately the same, on the average, as that at the end of the long 150-foot counter-

poise, although in 3 cases the current at the far end of the long counterpoise is in excess of that entering the short counterpoise at the tower. The greater effectiveness of the long counterpoise in discharging current to ground is indicated clearly by the data.

It was expected in the initial field instrument setup that a relation would be found between the currents measured in the tower legs and those measured in counterpoises. Currents measured in counterpoises and the tower leg to which they were attached have been plotted as frequency-magnitude curves in figure 4. The surprising features shown by these data, are, first, that the current in the long counterpoise is apparently greater than that in its tower leg; the current in the short counterpoise is more along the expected lines, being less than that in its tower leg. This may be partially explained by the fact that measurements in tower legs were made in the main legs of the tower and the cross lattice bracing may have shunted some appreciable part of the tower current past the measuring instrument. If this explanation for the larger current in the counterpoise than in the tower leg is correct then the individual tower leg currents shown in figure 2 would be considerably greater than indicated, which would bring that curve even closer to the curve of average lightning stroke currents in figure 2.

Typical data on current values in tower legs and counterpoises are given in table VII. These data show that although the ratio of currents in tower legs and counterpoises is remarkably constant in some cases from year to year or between one observation and the next one, there

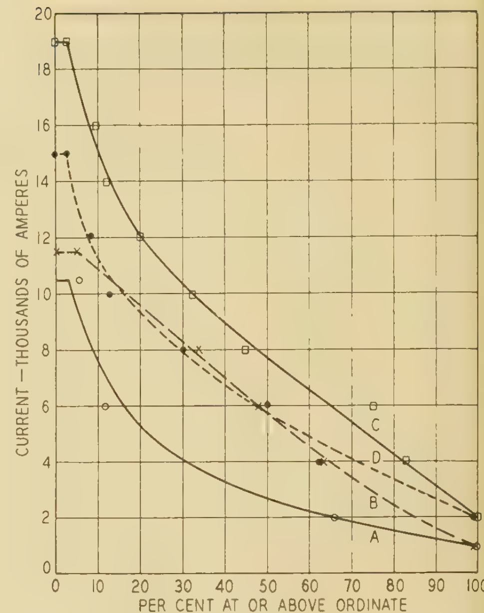

Fig. 4. Relation between currents in tower leg and attached counterpoise on Glenlyn-Roanoke line, 1934–35–36

A—Short counterpoise
B—Short-counterpoise tower leg
C—Long counterpoise
D—Long-counterpoise tower leg

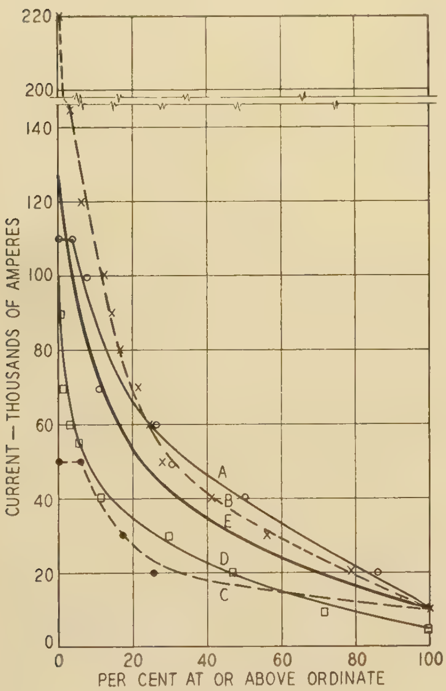

Fig. 2. Magnitude and frequency of lightning stroke currents, 1933–36

A—By ground-wire currents
B—Sum of adjacent tower currents
C—By tower-top lightning rods
D—Single tower currents
E—Average of *A*, *B*, and *C*

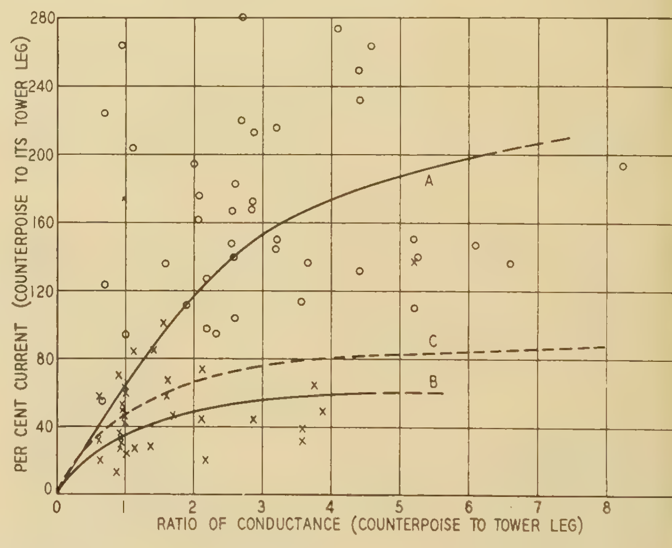

Fig. 5. Current distribution in counterpoises and tower legs on Glenlyn-Roanoke line, 1934–35–36

A—Result of test on long (150-foot) counterpoise; test points indicated by circles
B—Result of test on short (40-foot) counterpoise; test points indicated by crosses
C—Calculated on d-c basis

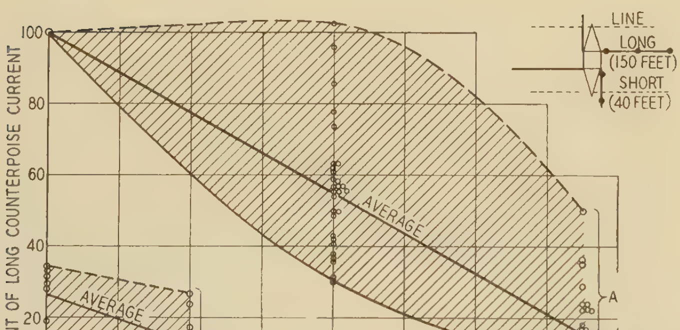

Fig. 3. Attenuation of lightning currents in counterpoises on Glenlyn-Roanoke line, 1935–36

A—Long counterpoise (30 records)
B—Short counterpoise (9 records)

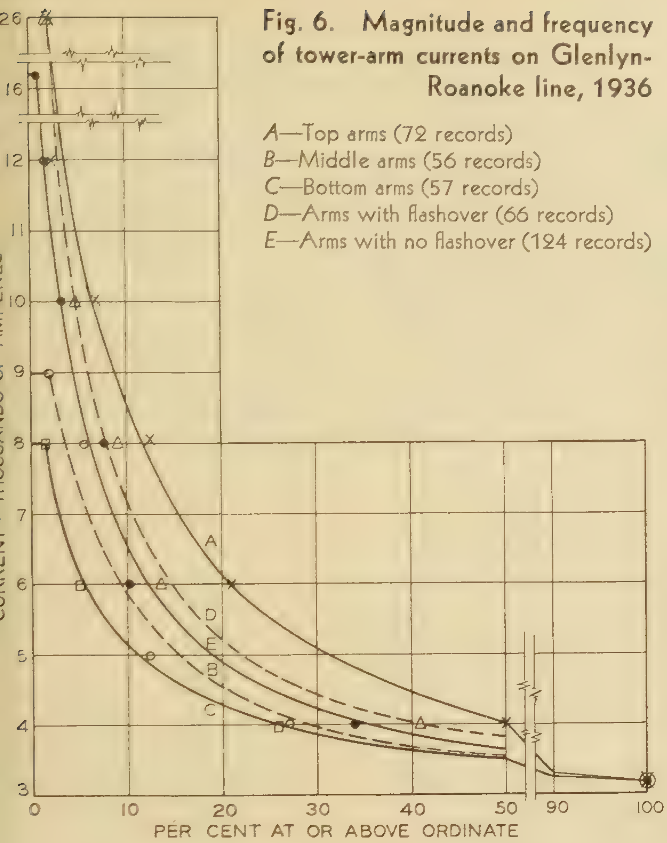

Fig. 6. Magnitude and frequency of tower-arm currents on Glenlyn-Roanoke line, 1936

A—Top arms (72 records)
B—Middle arms (56 records)
C—Bottom arms (57 records)
D—Arms with flashover (66 records)
E—Arms with no flashover (124 records)

re nevertheless many cases where a wide range of ratios xists. Thus, the table which gives the records at 9 owers which were subjected to a lightning disturbance om 2 to 4 times in the 3 years during which the observa- ions were made, it will be seen that at tower 18*R*, for xample, the ratio of current in long counterpoise to that n tower leg varied only from 1.65 to 1.47. At tower 21*G* the variation was from 1.09 to 1.39. Conversely, at tower 10*G* the variation ran from 0.55 to 2.28. Although it may be suggested that counterpoise and even tower leg resistances may have changed within a period of 2 years, it is, however, significant that ratios of from 2 to 1 for the long counterpoise current to tower leg currents, and from 3 to 1 for ratios of short counterpoise currents to tower leg currents have been obtained in the same year at the last mentioned tower, that is, 10*G*. It is suggested that these different ratios of current division between tower leg and counterpoise at a given location may be due to some extent to the difference of wave shape of the initiating lightning surge.

To aid further, an analysis of the current distribution in tower legs and counterpoises the data in figure 5 are presented. Here the ratio of current in the counterpoise to that in its tower leg has been plotted against the ratio of conductance of the same counterpoise to the same tower leg. The conductance of the tower leg has been calculated from the tower footing resistance measured before counterpoises were installed, (the tower, of course, being disconnected from the ground wire) on the assumption that the resistance of each tower leg footing was equal, that is, the resistance of one tower leg was 4 times the measured resistance of the 4 legs of the towers. The "shotgun" diagram of figure 5 does not permit drawing curves with any high degree of certainty. However, a characteristic trend is definitely indicated both for the long counterpoise and the short counterpoise.

If it is assumed that the current distribution in the ground at the foot of the tower is on the basis of measured resistance only, then the current division should be proportional to the conductance of tower leg and counterpoise. Such a distribution of current is shown by the dotted curve in figure 5. An examination of that curve

Table VII—Lightning Currents in Counterpoises and Tower Legs; Glenlyn-Roanoke Line, 1934–35–36

Tower Number	Year	Resistances—Ohms			Currents—Amperes				Current Ratios—Counterpoise to Tower Leg	
		Tower*	Long CP	Short CP	Tower Leg†	Long CP	Tower Leg‡	Short CP	Long CP	Short CP
20*G*	1934	15	21	90	10,300	10,000	9,000	2,900	0.98	0.32
20*G*	1935		21	90	4,300	9,400	8,000	1,600	2.18	0.20
20*G*	1936		21	90	6,800	19,000	5,200	3,000	2.80	0.58
21*G*	1934	140	107	196	9,200	10,000	9,600	3,900	1.09	0.41
21*G*	1935		107	196	7,700	10,700	7,700	2,400	1.39	0.31
22*G*	1934	96	86	237	2,500	6,200			2.48	
22*G*	1935		86	237	13,300	17,500	11,500	6,800	1.32	0.59
22*G*	1936		86	237	2,400	5,600	2,400	1,600	2.33	0.67
26*G*	1935	198	250	477	2,000	2,900			1.45	
26*G*	1936		250	477	3,600	7,700	2,800	1,300	2.14	0.47
26*G*	1936		250	477	2,400	3,600			1.50	
7*R*	1935	43	65	168	2,500	3,500	2,000	1,200	1.40	0.60
7*R*	1936		65	168	7,200	7,500	8,000	3,600	1.04	0.45
7*R*	1936		65	168	9,000	7,300	3,000	1,300	0.81	0.43
18*R*	1936	103	161	442	4,800	7,900	4,700	3,300	1.65	0.70
18*R*	1936		161	442	9,300	13,700	8,800	3,300	1.47	0.38
20*R*	1936	92	127	347	10,000	17,000	4,200	2,200	1.70	0 53
20*R*	1934		127	347			2,300	1,400		0.61
21*R*	1934	61	118	223	3,500	5,600	3,000	2,600	1.60	0.87
21*R*	1934		118	223	4,300	7,500	3,600	3,000	1.75	0.83
21*R*	1936		118	223	8,000	7,800	7,700	2,200	0.98	0.29
21*R*	1936		118	223	2,000	2,500			1.25	
10*G*	1935	60	347	107	2,500	5,700	2,000	900	2.28	0.45
10*G*	1936		347	107	12,500	6,800	4,500	3,300	0.55	0.73
10*G*	1936		347	107	7,000	8,600	7,500	1,600	1.23	0.21
								Average	1.56	0.51

Tower alone without counterpoise.
Tower leg attached to long counterpoise only.
‡ Tower leg attached to short counterpoise only.
CP = counterpoise.

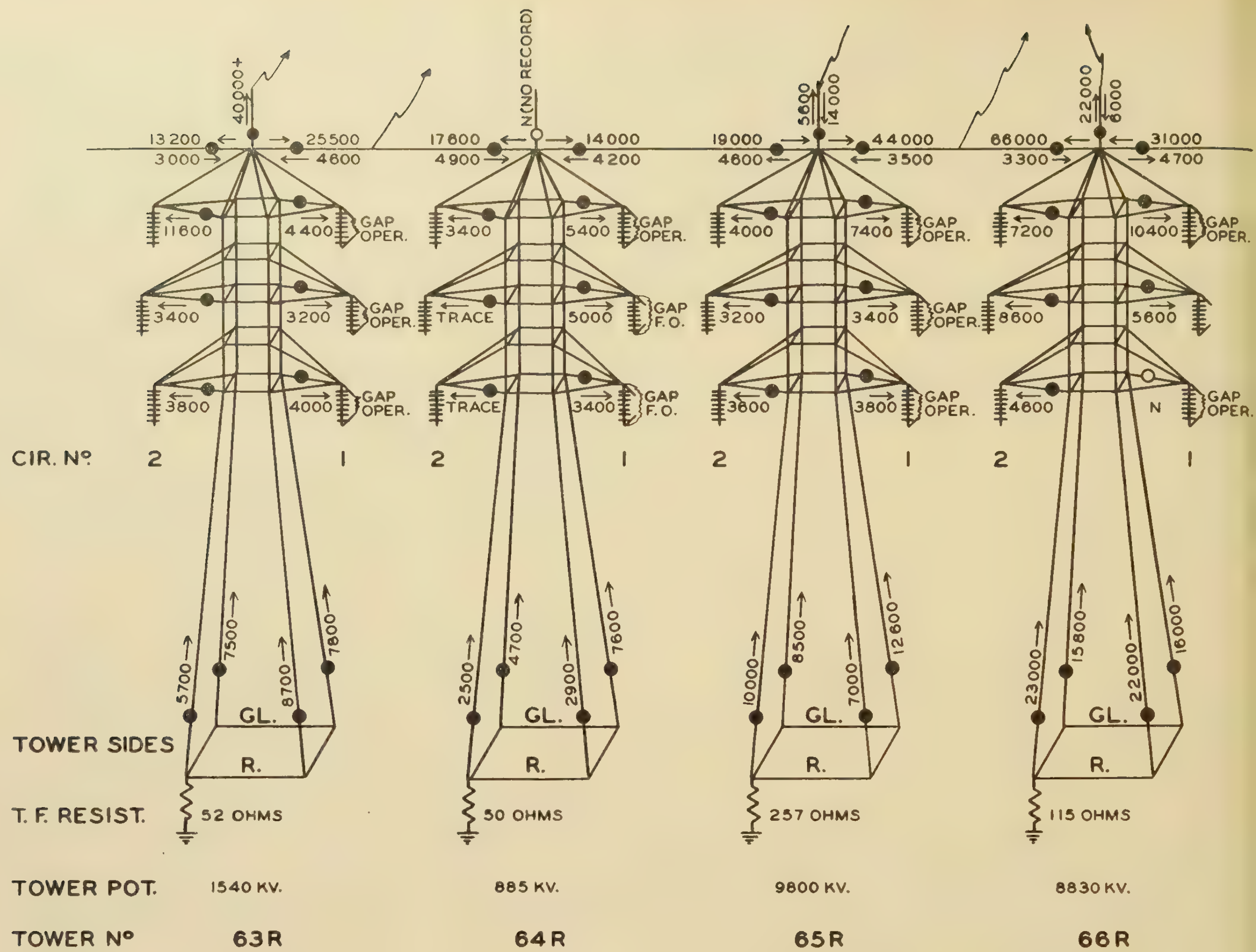

Fig. 7. Lightning currents measured in towers of 132-kv Glenlyn-Roanoke line, May 4–15, 1936

and of the 2 others in figure 5 seems to indicate that the short counterpoise apparently behaves very closely along the lines expected from a straight d-c characteristic, but that the long counterpoise carries considerably more current than can be explained from the standpoint of a d-c characteristic. It is recognized that the data shown in figure 5 are perhaps too erratic to permit definite conclusions, but the general trend seems to be indicated.

Tower Potential

In the past in analyzing field records of currents in towers, a procedure of multiplying tower current by the tower resistance was frequently employed to indicate potentials which could be compared with line insulation flashover and thus determine whether or not insulator assemblies should have been expected to flashover under the conditions encountered. In the authors' investigation work, in general, high tower potentials obtained in this way have almost, without exception, correlated with flashovers at towers carrying these high potentials. There are on record, however, a few cases where flashover marks have been found on insulator assemblies and high tower potentials were not obtained by the method of calculated *IR* drop outlined here.

With the values of tower footing resistances and counterpoise resistances known, it is possible from the data obtained to make a comparison between the *IR* drop in the tower footing and the *IR* drop in long counterpoise and short counterpoise. This interesting comparison is given in table VIII. Columns 9, 10, and 11 give the voltage comparisons by these 3 methods of analysis. It may be noted that there is no regular consistency in the tower voltages indicated, although frequently there is very good agreement between the readings obtained by 2 methods, but the third method is distinctly out of line. There are, of course, a number of variables which cannot be evaluated readily and it seems that some of these will have to be investigated further before any general agreement can be reached as to the accuracy of determining tower potentials by any of these 3 methods.

Tower Arm Currents

At the start of this work in 1933, in concentrating on the measurement of lightning currents, the surge-crest ammeter was recognized as a device which, when located on tower arms, had the possibility of indicating whether or not insulator assembly flashover had taken place

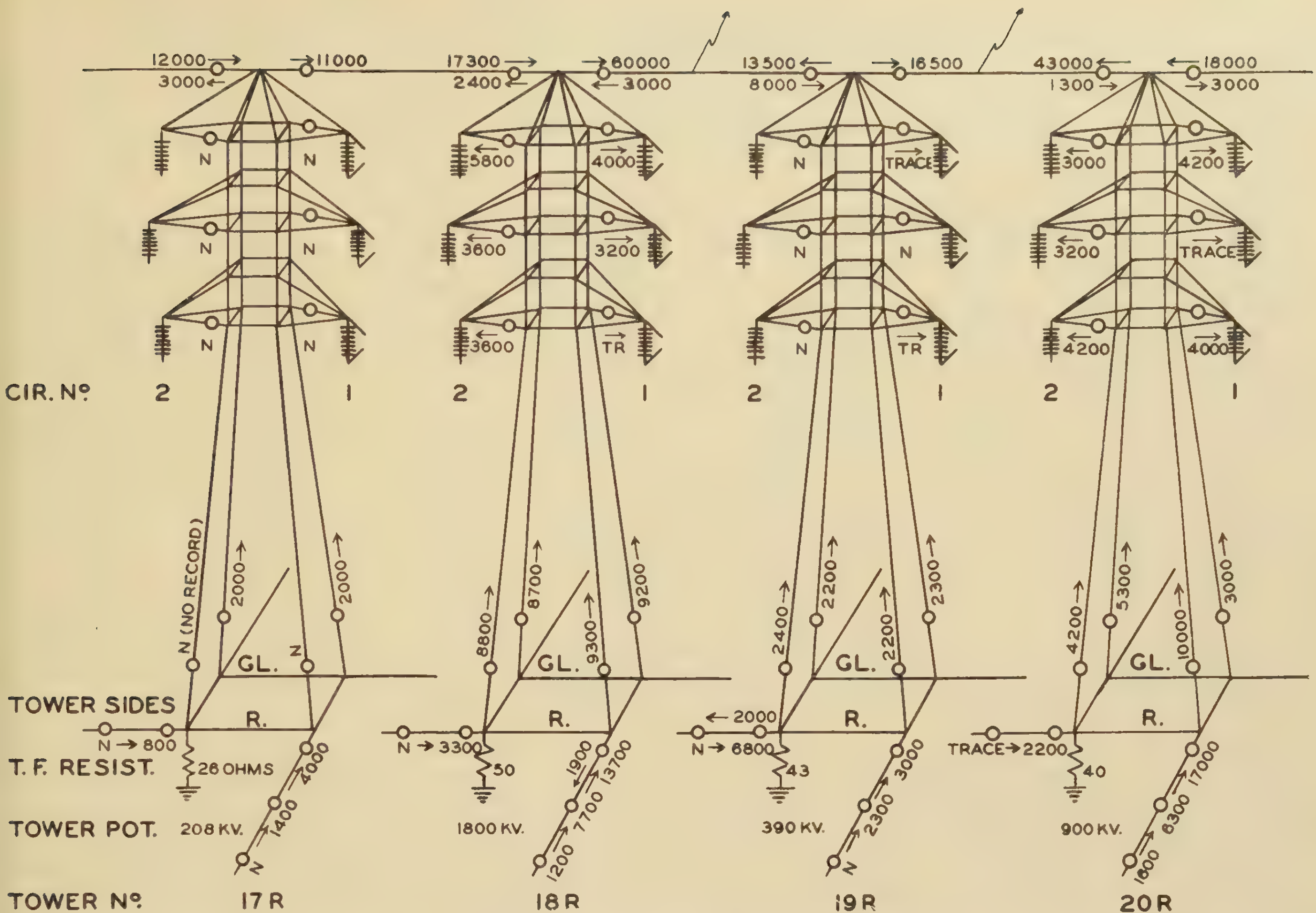

Fig. 8. Lightning currents measured in towers of 132-kv Glenlyn-Roanoke line, August 31–September 16, 1936

The original application was made primarily for this purpose. As the work progressed, however, it appeared that it was possible to obtain calibrated current readings, and the records have been gone over and correlated on this basis. The summarized data on current readings in tower arms are shown in figure 6. The outstanding point brought out by this group of curves is that the currents in the top tower arms were the highest, in the lower arms the lowest, and in the middle arms slightly greater than in the bottom arm but considerably less than

Table VIII—Tower Potential Where Flashover Occurred; Glenlyn-Roanoke Line, 1936

Counterpoise Section Only

Number	Tower Resistance‡ Ohms	Insulators Flashed Over	Tube Operated	Tower* Current—Amperes	Long Counterpoise† Current—Amperes	Long Counterpoise† Resistance—Ohms	Ground Wire Amperes at Tower	Kilovolts Tower IR	Kilovolts Long Counterpoise IR	Kilovolts Short Counterpoise I_cR_c	Short Counterpoise† Current—Amperes	Short Counterpoise† Resistance—Ohms
6*R*	66	Yes	Yes	59,000	16,700	237	17,800	3,894	3,957	7,600	−17,000	447
6*AR*	80		Yes	24,300	13,300	197	20,000	1,944	2,620	3,320	10,500	317
7*R*	19		Yes	21,300	7,300	65	13,500	405	474	220	1,300	168
26*G*	115		Yes	10,600	7,000	250	28,000	1,219	1,925	620	1,300	477
27*G*	96	Yes		N	3,400	168	15,000		571	330	1,100	300
28*G*	41		Yes	6,200	3,400	150	14,500	254	510	212	1,000	212
22*R*	15		Yes	N	2,500	31	12,200		77	50	1,100	45
24*G*	35		Yes	N	1,200	86	11,800		103			
21*G*	85		Yes	N	3,200	107	12,600		342			
20*G*	8		Yes	23,400	19,000	21	3,700	187	399	270	3,000	90
19*G*	14		Yes	6,800	6,800	31	3,200	95	99	198	2,200	90
10*G*	27		Yes	28,600	12,500	347	33,000	772	4,337	350	3,300	107
7*R*	19		Yes	31,700	7,500	65	60,000	602	487	605	3,600	168
28*G*	41		Yes	29,000	11,800	150	26,000	1,189	1,770	805	3,800	212
18*R*	50		Yes	17,900	7,900	161	33,000+	895	1,272	1,460	3,300	442
11*G*	28		Yes	29,400	7,400	132	12,200	823	976	238	2,500	95
10*G*	27		Yes	26,000	8,600	394	11,800	702	2,984	171	1,600	107
27*G*	96	Yes	Yes	33,400	13,500	168	46,000	3,206	2,234	1,170	3,900	300
23*G*	87		Yes	N	N	116	3,300					
18*R*	50		Yes	36,000	13,700	161	60,000	1,800	2,207	1,460	3,300	442
20*R*	40		Yes	22,500	17,000	127	43,000	900	2,159	760	2,200	347

Sum of currents in all 4 legs. † Data on counterpoise wire only. ‡ Including counterpoises.

Table IX—Lightning Currents‡ in Tower Structures for Ground-Wire Currents of 20,000 Amperes and More

Glenlyn-Roanoke Line, 1936

Tower		Tower		Tower	Lightning	Ground Wire	
Number	Resistance—Ohms§	Legs**	Counterpoises***	Arms†	Rods	Glenlyn Side	Roanoke Side
55*R*	75	34,100	#	−21,800	14,500	−45,000*	27,000
56*R*	47	42,900	#	−29,200	−12,300	6,700	−60,000*
59*R*	118	23,700	#	−20,800	2,000	−30,000*	15,700
60*R*	172	25,200	#	−16,600	− 2,000	12,000	−31,000*
62*R*	217	9,600	#	− 2,400		14,300	−29,000*
63*R*	53	29,700	#	−30,400	−40,000	−25,500*	−13,200
65*R*	257	38,100	#	−25,400	14,000	−44,000*	19,000
66*R*	115	76,800	#	−36,400	−22,000	31,000	−66,000*
6*AR*	80	24,300	47,600			−22,000	20,000
13*G*	11	20,500	16,400	−12,600		−25,000*	1,500
26*G*	115	10,600	18,000	− 3,000		−28,000*	14,300
21*R*	29	26,400	10,000	−19,400		−26,000*	9,700
22*G*	51	11,100	14,400	− 3,200		2,400	−35,000*
10*G*	27	28,600	31,600	− 7,800		−33,000*	12,000
7*R*	19	31,700	22,200	−15,100		−60,000*	10,500
28*G*	41	−29,000	−31,200	18,400		−16,700	26,000*
14*G*	12	9,300	26,600			− 2,200	−24,300*
18*R*	50	17,900	22,400	−23,800		−33,000*	12,000
60*R*	172	17,100	#	−13,400	2,000	−25,000*	6,800
68*R*	187	10,100	#	− 6,400		−21,500*	9,800
69*R*	37	11,800	#	− 6,800	− 2,000	7,000	−27,300*
28*G*	41	16,600	4,200	−19,400		−23,000*	6,000
27*G*	96	33,400	17,400	−17,200		9,700	−46,000*
18*R*	50	36,000	17,000	−20,200		−60,000*	17,300
20*R*	40	22,500	19,200	−18,600		18,000	−43,000*

* Probable lightning stroke in mid-span. ** Total of 4 legs. *** Two times current in 2 counterpoises. † Total current in all 6 arms. ‡ Currents toward tower top designated as positive. # No counterpoise installed. § Including counterpoise where counterpoise is installed.

in the top arm. It may also be noted that the solid curve of figure 6, which shows arm currents where flashovers of insulator assemblies were known to have occurred, accounts for currents as high as 26,000 amperes and as low as 4,000 amperes.

It is definitely known that tower-arm currents as low as from 3,000 to 5,000 amperes have been recorded in the field both with and without indication of insulator flashover. These can be accounted for even without line flashover, on the basis that the tower leg at the arm location is shunted by the arm and its hanger bar. This consideration leaves somewhat uncertain the interpretation of tower arm currents. High arm currents, in the order of from 10,000 to 26,000 amperes, were recorded in 1936 in only 5 cases, of which 2 instances were on flat-top towers without ground wires (of which there were 4 on the line). It is believed the remaining 3 cases were caused by direct strokes to the line conductors. This interpretation of tower-arm currents indicates a high degree of shielding afforded by the single conventional ground wire.

Ground Wire Currents

Measurements in the ground wire itself at each side of a tower were first obtained this year. Typical readings of currents in the ground wire are shown in table VIII, column 8. Currents above 20,000 amperes and their distribution have been tabulated separately in table IX. The highest current measured in the ground wire, it may be seen, was 66,000 amperes but there are 25 records of currents above 20,000 amperes. If currents of this magnitude are to be expected in wires of a transmission system subject to lightning, serious consideration must be given to keeping currents of such magnitude out of stations if station apparatus is to be protected. Also, consideration must obviously be given to the ability of protective devices to handle lightning currents of this magnitude, since these are considerably in excess of what has ordinarily been considered possible to reach a station where pre-station voltage limitation is provided for by steel tower construction and limited insulation for a reasonable distance beyond the station. Again, currents of this order, if they are to be taken as traveling waves associated with line surge impedance, indicate voltages far in excess of values which could exist on the line without flashover. There is room, therefore, in this connection for further research.

Typical Field Records

Typical field records showing currents obtained in tower legs, arms, ground wires, lightning rods, etc., have been charted in figures 7 and 8, and a close study of these, it is believed, will prove fruitful. It is from records of this type that the data summarized, presented, and discussed in this paper have been obtained. The double-reading indications on the ground wires in both figures are obtained from a proper câlibration of the surge-crest-ammeter records; the reverse directions of current flow apparently indicate reflections of current. In general, such current oscillations are absent or of small magnitude in tower legs, arms, and in counterpoise readings except in the last where they are sometimes encountered in combination with high current values.

Summary and Conclusions

Based on the field data obtained on lightning currents during the past 4 years, part of which has been presented in this paper, the following conclusions seem definitely warranted:

1. Although lightning stroke currents as high as 220,000 amperes have been indicated, it appears that the maximum stroke currents

(*Concluded on pages 259–60*)

Tooth-Frequency Eddy-Current Loss

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A method of recording, by means of an oscillograph, the eddy currents in various parts of the cross section of a squirrel-cage-rotor bar is presented in this paper. From such records the magnitude of the power loss caused by eddy currents, and its variation with load, may be determined. A series of tests of this nature has been made; the results, which the author believes to be correct in general, show that the change of eddy-current loss with load is negligible, thus simplifying the determination of the composite stray-load loss of a squirrel-cage induction motor.

THE eddy currents in a squirrel-cage rotor bar may be measured by a method that occurred to the author some time ago; the method permits recording by means of an oscillograph the current flowing at any particular point of a conductor cross section, if the cross section and the distribution of the current density in it remain substantially uniform throughout the portion of the conductor length along which the current flow is studied. A bar of a squirrel-cage rotor essentially satisfies these requirements, being of a uniform cross section, and having a uniform distribution of the current density, at least through the stacked-iron length of the bar.

At normal operating conditions the frequency of the fundamental working current in the bar is so low that the effect of the fundamental-frequency leakage flux upon the distribution of the current density throughout the bar cross section is negligible; that is, the main current is distributed almost uniformly throughout the cross section of the bar. This main current, however, is not by any means the only current flowing in the bars. Part of the fundamental air-gap flux passes through the slots, and hence through the conductors, and the pattern of this slot leakage flux pulsates at the frequency of the passing stator teeth.[1,2] As a result of this, tooth-frequency eddy currents are produced in the rotor bars, the amplitudes reaching a very substantial value in some parts of the bar cross section, as shown by observation. The method of recording such currents by means of an oscillograph, to be described later, provides a means of studying the current distribution in the bars and an experimental measurement of the attendant power loss. The determination of this power loss, its variation with load, and the study of factors causing its variation with load constitute the subject of this paper.

Results and Conclusions

The machine used for the experiments was a squirrel-cage motor, rated at 10 horsepower, 220 volts, 60 cycles, 1,200 rpm. The number of teeth in the stator was 72; the number of teeth in the rotor, 37. The shape of the rotor and stator punchings is given in figure 1, together with the dimensions of the rotor-bar section.

As should have been expected on the basis of A. B. Field's[3] and J. J. Thomson's[4] theories, the amplitude of the eddy currents was found to be a maximum on the surface of the bar (nearest to the air gap), decreasing rapidly with distance from the surface in the interior bar. The maximum amplitude of the tooth-frequency eddy-current density on the surface was several times greater than the main working current density. In spite of this, the power loss caused by the tooth-frequency eddy currents was found to be considerably less than the copper loss caused by the fundamental working current, because the region of the high eddy-current density is limited to a comparatively thin surface layer of the conductor facing the air gap.

The actual magnitude of power loss caused by tooth-frequency eddy currents, based on oscillographic records, was 27 watts. The copper loss caused by the main current, using the amplitude obtained from the oscillographic records, was computed to be 87 watts; as obtained from slip measurement, it was 85 watts. The values of the fundamental current loss were computed as a check upon the correctness of results obtained from the oscillograms.

The magnitudes of the tooth-frequency power loss just given remained substantially unchanged as the load was applied. If any change with load was observed in the particular motor tested, it was a decrease instead of an increase. Considering that the total power input to the motor at full load was approximately 10 kw, the tooth-frequency eddy-current loss constituted about 0.3 per cent of the power input at full load. Though this quantity itself is not entirely negligible, any observed change of it with load was much too small to be of any practical importance. The significance of this conclusion is obvious, for no convenient method of testing a motor for the change of this item with load is available. A possibility of neglecting it simplifies the problem of testing for the stray-load loss.

Though no experimental data on other motors is

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1. For all numbered references, see list at end of paper.

available, this conclusion very likely applies to all motors in general. There is every reason to believe that the tooth-frequency eddy-current loss in other motors has a relatively lower value than in the motor tested, for the latter had very thin rotor-tooth shoulders, and shallow slots, with a consequent large area of bar surface facing the air gap, where the eddy current density is particularly large.

Method of Measurement

The method of recording the current flowing at any point of the bar cross section can be explained

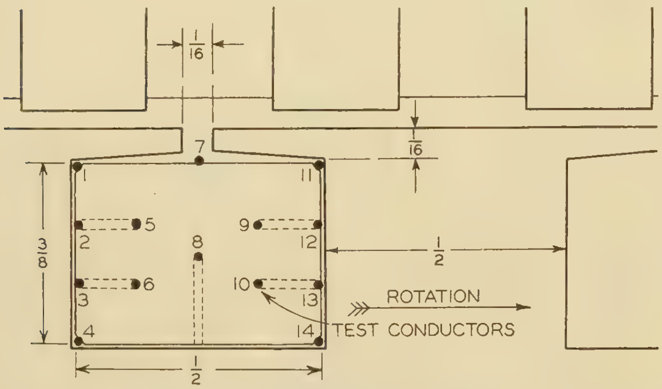

Fig. 1. Diagram showing dimensions of stator and rotor teeth and location of test conductors

Dimensions are in inches

with reference to figure 2. It requires placing an insulated test conductor a—b, within the bar material, and at that point of the bar cross section where the current to be recorded flows. One end of the test conductor a is connected directly to the oscillograph, and the other end is connected to the rotor bar at point c. Point d of the bar is the terminal of the other lead to the oscillograph. The instantaneous voltage appearing between leads a and d can be shown to represent correctly the density of the instantaneous bar current flowing along path a—b, that is,

$$e_{ad} = K\delta_{ab}$$

where e_{ad} is the voltage between leads a and d and δ_{ab} is the instantaneous current density along path a—b. This follows from consideration of the equation giving the total electric potential between points a and d

$$e_{ad} = \int_{abcd}\left[K_\varphi\frac{\partial B}{\partial t}\sin\beta + \delta\rho\cos\gamma\right]dl$$

where

B = magnetic flux density along the path of integration
β = angle between the direction of the magnetic flux and the path of integration
δ = current density along the path of integration
γ = angle between the direction of current flow and the path of integration
ρ = resistivity of the material

The subscript below the integral sign indicates the path along which the integral is taken. This integral can be divided into 2 parts:

$$e_{ad} = \int_{abc}[X]dl + \int_{cd}[X]dl \quad (1)$$

in which X denotes the quantity inside the brackets in the previous equation. The first term is taken along the test conductor and the second along some path within the bar. The path c—d, being arbitrary, can be taken along the surface of the conductor from c to b', then alongside the test conductor from b' to a', and on the surface from a' to d. The end surfaces of the bar are outside any magnetic influence and the current density along them is zero; therefore, all points of these surfaces are at the same magnetic potential. Hence, the integral along these surfaces will disappear, and

$$\int_{cd}[X]dl = \int_{b'a'}[X]dl$$

taken in the immediate vicinity of the test conductor in the bar material.

Considering now equation 1 again

$$e_{ad} = \int_{abc}[X]dl + \int_{b'a'}[X]dl$$
$$= \int_{abc}K_\varphi\frac{\partial B}{\partial t}\sin\beta dl + \int_{abc}\rho\delta\cos\gamma dl +$$
$$\int_{b'a'}K_\varphi\frac{\partial B}{\partial t}\sin\beta dl + \int_{b'a'}\rho\delta\cos\gamma dl \quad (2)$$

Since the paths a—b and b'—a' are in the immediate vicinity, and neglecting the integral along b—c,

$$\int_{ab}K_\varphi\frac{\partial B}{\partial t}\sin\beta\cdot dl + \int_{b'a'}K_\varphi\frac{\partial B}{\partial t}\sin\beta dl = 0 \quad (3)$$

Also, if the circuit of the test conductor is linear, with impedance Z, and current i taken by the oscillograph,

$$\int_{ab}\rho\delta\cos\gamma dl = -iZ \quad (4)$$

The use of equations 4 and 3 reduces equation 2 to

$$e_{ad} = -iZ + \int_{b'a'}\rho\delta\cos\gamma dl$$

When the distribution of current density is uniform along the bar, δ is constant, $\gamma = 0$, and this expression reduces to

$$e_{ad} = -iZ + \rho\,\delta_{b'a'}l \quad (5)$$

$\delta_{b'a'}$ being the current density in the bar along the test conductor. The condition of uniformity of the distribution of current density is fulfilled along the

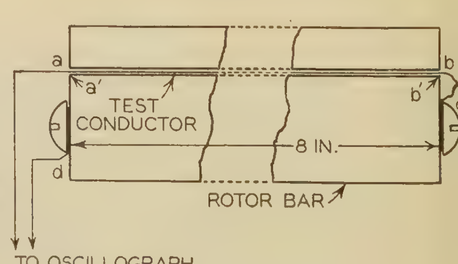

Fig. 2. Sketch of the device used to detect eddy currents in various parts of the cross section of a rotor bar

Fig. 4. Oscillograms of tooth-frequency eddy currents in the trailing outer corner of a rotor bar for various conditions of operation

A—No load

B—Motor load

C—Generator load

D—Motor load with bar disconnected

major part of the bar length. The ends of the bar near and beyond the length of stacked iron undoubtedly introduce a slight irregularity in the resultant voltage, but the effect of this irregularity cannot be important practically.

The use of a vacuum-tube amplifier was found to be necessary to record the voltage $a—d$ on the oscillograph. This further simplified equation 5, for $i = 0$ and

$$e_{ad} = \rho\delta_{b'a'}l$$

This equation merely states that the voltage between points a and d is proportional to the current density in the bar along $a—b$.

For the purpose of the present study 14 conductors were placed in one rotor bar, 9 of which were located at different points on the surface, and 5 inside of the bar. The location of the test conductors is given on figure 1.

To place the conductors inside the bar, slots 25 mils wide were milled as indicated by the dotted lines on figure 1 to the depth at which the test conductors were to be placed. A steel piano wire of a diameter slightly larger than number 26 enamel-insulated copper wire, used for the test conductors, was then placed at the bottom of the slots, and the slots were filled with sheet copper, soldered to the walls of the slots. After pulling out the steel wire, very fine canals were formed parallel to the axis of the bar, just large enough to place the test conductors inside without injuring the insulation. This method of placing the test conductors inside of the bar impares somewhat the homogeneity of the bar material. It is doubtful, however, that the effect can be appreciable, for the layers of solder introduced were extremely thin.

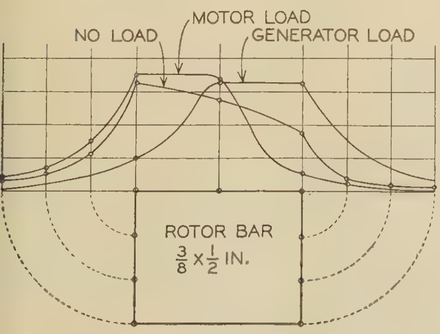

Fig. 3. Diagram showing distribution of the amplitude of tooth-frequency eddy currents on the surface of a rotor bar

The scale of amplitude is in hundredths of an inch

With the 14 test conductors a series of oscillograms was taken, one set of 3 different conditions of operation for each of the test conductors. These conditions of operation were:

1. No load, motor idling on a line at rated voltage.
2. Approximately full motor load at rated voltage.
3. Generator load at rated voltage, with the slip the same as for the second test.

The general character of the eddy current wave can be obtained from the reproductions of some of the oscillograms given in figure 4.

Effect of Load

Before considering the power loss caused by the tooth-frequency eddy currents, it seems advisable to understand the factors producing a change in this loss as the motor is loaded. The only factor producing the tooth-frequency flux pulsation in the rotor slots at no load is the tooth-frequency component in the permeance distribution along the stator periphery. When the motor is loaded, the load currents produce an additional component of the tooth-frequency flux, because of the tooth-frequency component in the distribution of the magnetizing force along the stator periphery. As a result, the amplitude of the tooth-frequency pulsations may be expected to increase with load.

Actually the situation is considerably complicated by the effect of saturation of the rotor-tooth shoulders, produced by the combined effect of the rotor leakage flux and the main air-gap flux of the machine. The observed distribution of the eddy-current density for different load conditions can be seen from the oscillograms of figure 4 and also from figure 3, which gives the distribution of the eddy-current density on the surface of the bar, obtained from the oscillograms. An almost symmetrical distribution for no load becomes greatly distorted when the machine is loaded either as a motor or as a generator, but the character of distortion is different in the 2 cases. For motor operation, the amplitude of the tooth-frequency eddy current is increased in the region of the trailing

corner of the bar and greatly decreased in the leading corner. For generator operation, the effect is reversed: the amplitude is greatly decreased in the trailing corner of the bar, and increased in the leading corner. This difference between motor and generator operation immediately suggests the explanation of the phenomenon, which can be readily understood with reference to figure 5. This illustration shows the relative direction of the main flux and rotor-leakage flux in the rotor-tooth shoulders. As can be seen from figure 5*a*, when the machine is operated as a motor the leading (with respect to the center of the bar) tooth shoulder operates at a lower flux density than does the trailing tooth shoulder, for the main and rotor leakage fluxes here oppose each other. As a result of this low flux density, the leading tooth shoulder acts as an effective magnetic shield, reducing the influence of the tooth-harmonic flux in the leading

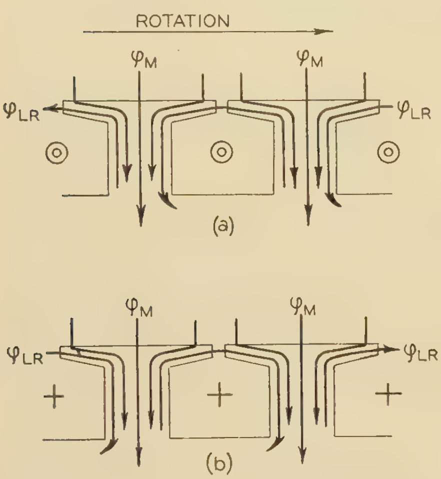

Fig. 5. Diagrams illustrating the effect of rotor leakage flux and main flux upon the magnetic saturation in the rotor-tooth shoulders

(*a*)—Machine operating as a motor
(*b*)—Machine operating as a generator
ϕ_M—Main flux
ϕ_{LR}—Rotor leakage flux

corner of the bar. The trailing tooth shoulder, on the contrary, operates at a high flux density and therefore produces little or no shielding effect. When the machine is operated as a generator the direction of the leakage flux reverses with the resultant reversal of the effect in the leading and the trailing corners of the bar. A conclusive proof of the origin of the redistribution of eddy-current density with load is obtained by operating the machine with the test bar disconnected from the short-circuiting ring at one end, thus preventing the main current from flowing. Under this condition the effect was found to disappear, because the leakage flux had been largely eliminated.

For the particular motor used the effect of saturation in the tooth shoulders was pronounced, as can be seen from figures 3 and 4. The net change of power loss produced by the effect may be either an increase or a decrease, depending upon the design of the punchings and the conditions of operation. Without attempting a rigorous analysis, the design of the punchings and the conditions of operation may be said to affect the eddy-current redistribution in the following way: When the shoulders are operated at a fairly high fundamental flux density, so that their shielding effect is small, the addition of the leakage flux may be expected to result in a decrease of the total eddy-current loss. This result may be expected because the increase of flux density in one of the shoulders will not reduce its shielding effect appreciably, being small already. On the contrary, a decrease in the flux density in the other tooth shoulder may bring it to a point of high permeability, and hence increase the shielding effect of the shoulder more than enough to offset the decreased shielding effect in the other shoulder in their common effect upon the eddy-current losses. The opposite result may be expected, if the main flux alone does not saturate the shoulders. The eddy current loss in the conductors remains low at all times, if the shoulders provide effective shielding at all loads, that is, when no saturation is caused even by the combined action of the main and the leakage fluxes.

Method of Computation

For the purpose of computing the tooth-frequency eddy current loss in the rotor, using the observed current amplitude distribution, Field's equation, giving the distribution of the eddy current density inside of a solid piece of conducting material in terms of the current density on the surface, was employed:

$$\delta_x' = e^{-mx}\delta_s' \sin(\omega t - mx) \tag{6}$$

where

δ_x' = instantaneous current density at a distance x from the surface along a normal
δ_s' = current density on the surface

$m = 2\pi\, 10^{-4} \sqrt{\dfrac{\mu f}{10\rho}}$

μ = permeability of the material
f = frequency of the eddy currents
ρ = resistivity of the material

This equation states that the eddy-current density distribution along distance x normal to the surface has a character of an attenuated wave. For the purpose of this analysis, only the total amplitude variation with x, instead of the instantaneous value of δ_x' is of importance. This is obtained by dropping the function $\sin(\omega t - mx)$, which reduces equation 6 to

$$\delta_x = \delta_s\, e^{-mx} \tag{7}$$

where δ_x and δ_s denote the total amplitudes of the eddy currents at a depth x, and at the surface, respectively.

Equation 6 is developed for the following conditions: (1) uniform phase and amplitude of δ on a plane surface; and (2) a piece of material thick enough to allow the eddy-current wave to disappear largely before it reaches another boundary surface, that is, there is an absence of reflections of the wave within the conductor.

The first of these 2 conditions is not realized in the actual case observed. This fact is accounted for later in the application of equation 6. The second condition is sufficiently realized for the observed eddy current amplitude attenuates with sufficient rapidity to obviate any appreciable effect of reflections. In

(*Concluded on page 260*)

Reactance of End Connections

By J. F. H. DOUGLAS
MEMBER AIEE

Use of image conductors in iron, of Rayleigh insulating partitions, and of images of conductors in these partitions is shown in this paper to afford one possible line of attack on the problem of the reactance of the end connections of electrical machinery. The use of 2 other methods to reduce the field in the end zone to a basis where Ampere's equation may be correctly applied is also suggested.

THE PURPOSE of this paper is to suggest certain lines of attack upon the problem of end-connection reactance, which it is hoped will lead to more accurate formulas than are available at present. No completed solutions are given, because it is felt that the proposals should be discussed thoroughly before the details are filled in by calculation. In this way the path will be clearer for further research.

There are 2 methods of approach at present to the subject of end-connection reactance. The first consists in supposing the poles, armature, iron, and slot conductors removed, and the end-connections joined. On this basis, Ampere's equation may be applied and formulas for the specific permeance of self-induction per centimeter of end turn found. These expressions are of the type

$$P' = 0.2 \log_e \frac{D}{r} + C \tag{1}$$

In this equation D is the diameter of a circular or the side of a square end-connection, r is the geometric mean radius of the coil, and C is a constant depending on the form of the coil and may be approximately from -0.05 to -0.10.

A second line of approach is to assume a potential function over the surface of the end-connections of the form

$$V = M \sin (\pi x/A) \cos (\pi y/B) e^{-Cz} \tag{2}$$

In this equation A is the pole pitch, B is the axial length of both end connections, and C is chosen to satisfy Laplace's equation. The x co-ordinate is measured parallel to the circumference, y parallel to the shaft, and z along a radial line. The origin is at the intersection of the armature surface, the point of reversal of magnetomotive force, and a plane perpendicular to the shaft and flush with the pole ends.[1]

It will appear from the discussion that both of these lines of approach are equivalent to an erroneous placement of a Rayleigh flux partition perpendicular to the shaft and flush with the pole ends. The second equation also implies a Rayleigh conducting partition placed perpendicular to the shaft and at the ends of the armature winding.

The assumptions made in this paper are as follows: Ampere's law may be applied to determine end-connection fields, provided image conductors are assumed in certain Rayleigh conducting and insulating partitions. When a plane iron surface is slotted, and there is a difference of magnetic potential across the gap thus formed, the gap may be closed with a fictitious conductor carrying current opposite to the currents establishing that difference of potential. The Schwarz - Christoffel theorem may be used to transform certain known fields into other new and useful fields with different boundary shapes. Rayleigh insulating partitions may be placed perpendicular to the shaft only so as to join the edges of the pole in the interpolar regions. Radial Rayleigh insulating partitions may be placed at the edges of the poles so as to divide the end zones into polar and interpolar regions.

Inductance and D-C Machines

Figure 1 shows several examples of conductors near iron. The symbol S is used to denote stator iron, R rotor iron, P polar iron, Y yoke iron, and A armature

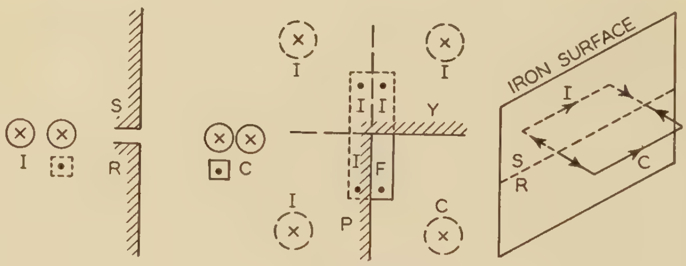

Fig. 1. Image coils in iron

iron. The symbol C denotes an armature end conductor, and F a field coil. By placing the image conductors I as shown the iron surfaces may be eliminated because of the symmetry. The figure shows several important cases. At the left is shown a basis for the leakage inductance of an induction motor, in the center a basis for the inductance of a coil of a d-c machine undergoing commutation, and at the right the means in part for estimating open-circuit reactance of an induction motor. So far as these fields are 2-dimensional, reference may be made to

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1. For all numbered references see list at end of paper.

Hague,[2] who has developed the idea of image conductors in a number of cases.

Several examples of the use of a fictitious conductor *FC* to close an air gap and establish a required potential difference across the gap are shown in figure 2. The current must be equal and opposite to that in the other coil. There are image conductors in this case also, but for simplicity they are not shown. They are governed by the same rules as in figure 1. At the left in figure 2 is a basis, in part, for the estimation of the open circuit inductance of an induction motor; in the center is a basis for estimating pole-end leakage from a d-c machine; and at the right there is combined the left-hand picture of figure 2 with the right-hand picture of figure 1 as the complete picture of 2 coils co-operating to establish 2 iron surfaces at a definite difference of potential.

Figure 3 shows a conductor C in the corner between 2 perpendicular Rayleigh partitions. The plane RI is an insulating plane, while RC is a conducting plane. This gives rise to the image conductors as shown, and the inductance of this field may be found by Ampere's equation. The Schwarz-Christoffel[3] equation may be used to transform the field in the quadrant to that in the infinite half plane shown at the right. The equations applying to this case are

$$dz/dt = S\sqrt{t} \qquad t/a = (z/a)^2 \tag{3}$$

where $(z = x + jy)$ is the co-ordinates of any point in the Z plane or left-hand figure, and $(t = q + js)$ is the co-ordinates of the corresponding point in the T plane or right-hand figure. The inductances of the 2 fields are the same. The radius of the conductor is doubled, and the angle θ doubled in the right-hand figure. This boundary condition is useful in estimating inductance of end connections in one of the zones into which the field may be divided.

Figure 4 shows 2 current elements symmetrically located on either side of a plane surface. The figure shows the elements, a point P on the plane of symmetry, the radii vectors from the elements to the point P, and the angle between the elements and the radii vectors, all in orthographic projection. Two cases are shown establishing conditions for the plane of symmetry being respectively a Rayleigh insulating and a Rayleigh conducting plane. It is the basis for establishing image conductors for the 3-dimensional case.

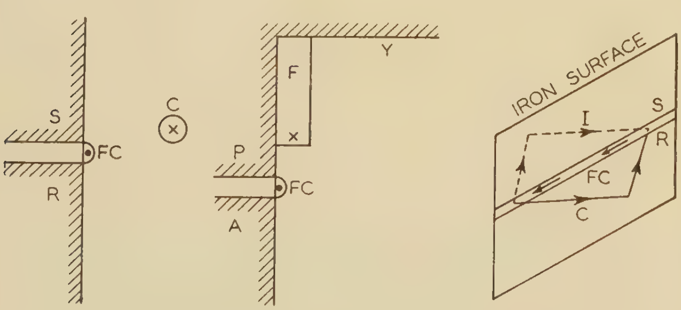

Fig. 2. Fictitious conductor closing gap

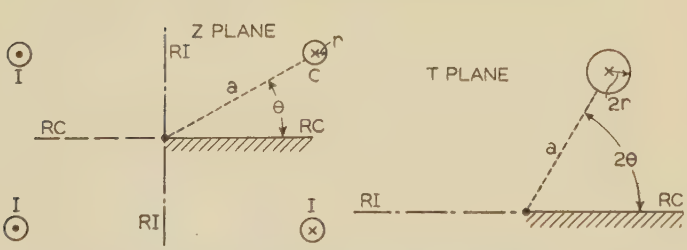

Fig. 3. Rayleigh planes and conformally transformed field

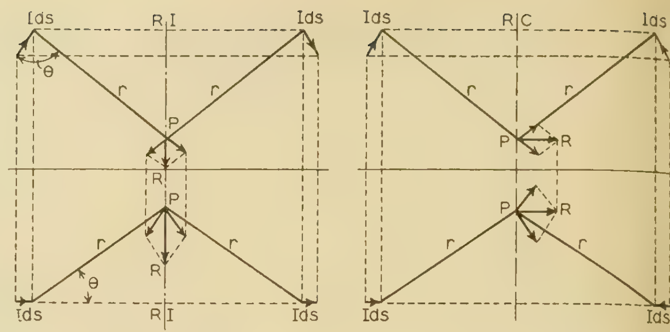

Fig. 4. Ampere's law and Rayleigh planes

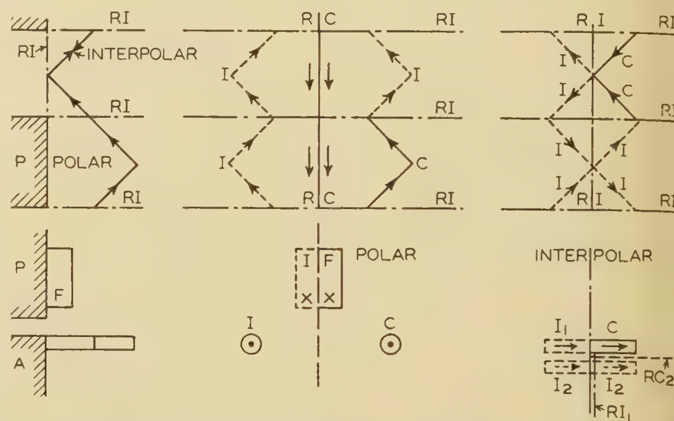

Fig. 5. Image conductors, direct reaction

Synchronous Machines

In figures 5 and 6 the end connection field of a synchronous machine is analyzed and methods of computing inductance are established. In figure 5 directly magnetizing conditions are shown, and in figure 6 transversely magnetizing conditions are shown. At the left of both figures the poles, the interpolar spaces, and the armature iron, as well as the field and armature coils, are shown in orthographic projection. Also shown are assumed insulating Rayleigh partitions, dividing the end connection zone from the zone over the armature surface, and dividing the end-zone into 2 regions, namely a polar zone opposite the polar iron, and an interpolar zone opposite the interpolar regions. Although these assumed planes cramp the flux, it is believed that less error results from them than from those used as the basis of present formulas. The insulating Rayleigh planes are designated by the symbol RI. The iron surfaces constitute Rayleigh conducting planes.

In the center and right-hand parts of figure 5 the Rayleigh partitions, the coils of the armature and

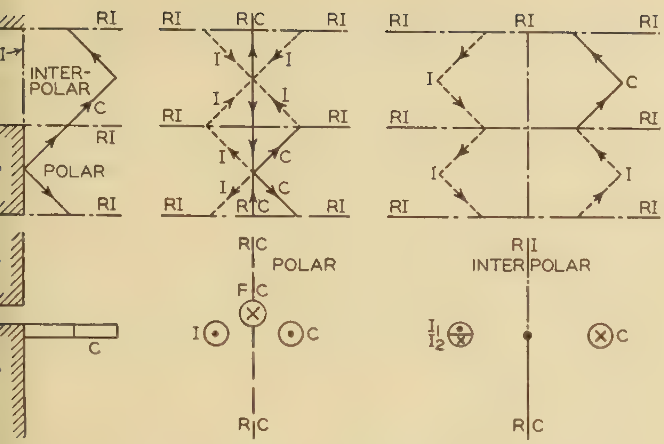

Fig. 6. Image conductors, transverse reaction

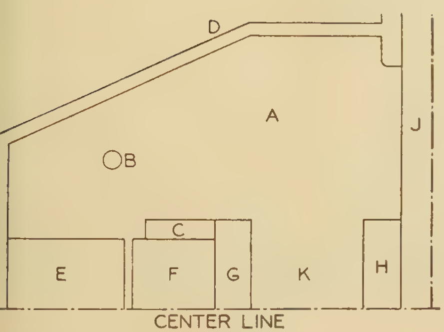

Fig. 7. Experimental analogue for testing end-connection reactance

A—Water trough
B—Brass rod at trace of armature coil
C—Muller brush electrode at trace of field coil; 128 wires lead in
D—Housing iron
E—Armature iron
F—Field iron
G—Yoke iron
H—Spider iron
J—Shaft iron
K—Rayleigh insulating plane; made of copper in model

All iron surfaces are made of insulation in model

eld designated by C and F, and their images are hown. In the center figure the image system for the olar zone is shown, and in the right-hand figure the nage system for the interpolar zone. In the elevaion view of the interpolar zone an inconsistency may e noted, caused by the vertical plane being in part n insulating, and in part a conducting plane. This nay be resolved in 2 ways. If the line RI is assumed o be drawn adjacent to the armature too small an ductance is obtained, but there is the image system which can be calculated. On the contrary, if a ayleigh conducting plane RC_2 is placed just under he armature conductors, the image system I_1 and I_2 obtained which gives an inductance approximately wice as great as the former, and which is too large. compromise value will therefore be subject to an ncertainty of 33 per cent. It is hoped that discuson may show the way to a better solution of this articular zone.

In figure 6 there is at the left the orthographic rojection of the machine structure, together with asmed Rayleigh insulating partitions. In the center the image system in the polar zone and in the right hand part is the image system in the interpolar zone. In this case, in the polar zone, it is necessary to introduce the artifice of the fictitious conductor for closing the gap and establishing the needed difference of potential across the gap, between the polar and armature iron. In the elevation at the right it may be noticed that the image of C is either I_1 or I_2 according to whether the line RI or RC is taken for forming the image. This case is really the Rieman surface which was resolved in the discussion of figure 3.

If the basic assumptions indicated here should prove valid, a program of research would include the evaluation of the inductance of single coils, groups of coils, and the effect of mutual inductance. This would be built up into combined coefficients for the 3 symmetrical components of current and for both the steady and the transient states.

The effect of variations in the boundary conditions such as those caused by the proximity of iron of the frame, housing, and shaft may in some cases be resolved by the Schwarz-Christoffel transformation, but the greatest promise is offered by the use of an experimental method devised by Mullner.[4] In figure 7 is shown a diagram of a water tank in which the conjugate field of end connections may be set up, in the form of an electrokinetic analogue. The experimental arrangements include a brush electrode for a field coil, a circular rod for the armature coil, and the use of copper on the boundary for Rayleigh insulating partitions and of insulation on the boundary for Rayleigh conducting partitions.

A solution of the problem of end connection inductance is to be desired not only for its own sake, but also as an aid in estimating of losses caused by such fields in nearby metal.

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Lightning Currents in 132-Kv Lines

(Continued from page 252)

rarely exceed about 150,000 amperes. Only 10 per cent of the measured currents were in the range above 70,000 to 100,000 amperes.

2. Single-tower currents showed 100,000 amperes as a maximum, with 10 per cent of them above 45,000 amperes. Apparently fairly definite relationships between current magnitude and frequency of occurrence exist. Such data used in combination with tower-footing resistances are helpful in predicting the lightning performance of transmission lines.

3. Counterpoises in the order of 40 feet long are far less effective in discharging lightning currents to ground than longer counterpoises of say 150-foot length, the ratio of currents being in the order of 1 to 4 respectively at the point of attachment to the tower.

4. The short counterpoise not coupled with the line discharges

lightning currents in a manner closely following its expected performance from the standpoint of its ohmic conductance to ground. The long counterpoise, coupled with the line (underlying it), discharges currents of the order of twice this value, on the average.

5. Currents recorded in tower arms have yielded no conclusive data. It would appear that in view of the fact that only 3 records of currents were obtained in 1936 in excess of 10,000 amperes, under conditions attributable to direct strokes to line wires, that the present typical construction with one ground wire of the Glenlyn-Roanoke line is giving a high degree of shielding of the line wires. Two similar records were obtained at one point on the line, where for structural reasons the ground wire was absent.

6. The high currents measured in the ground wires (66,000 amperes maximum) indicate the necessity of adequate shielding of the line at station entrances. They also clearly show the need of knowing more definitely the characteristics of lightning-protective devices, in view of the possibility of much higher currents through these devices than have been considered in the past.

7. Previous field investigation work on lightning effects on electrical lines and equipment has yielded many valuable data which are useful in evaluating the factors affecting the operating performance of such equipment under lightning conditions.

The breaking down of the over-all picture of lightning on a line into its component parts, to determine the currents in the various parts of the electric circuit as covered by the planned investigation work presented in this paper, is beginning to give a clearer understanding of what is actually taking place in the various parts of the entire lightning circuit. The situation is steadily being approached where lightning currents in the electric system can be predetermined with some degree of assurance, which should be of paramount value in providing protection to lines and equipment and determining the duty on protective equipment. However, a great deal of the unknown remains to be explored.

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Tooth-Frequency Eddy-Current Loss

(*Continued from page 256*)

fact, it decays faster than is predicted by equation 6, which is probably a result of the phase difference between eddy currents at different points of the bar surface. It follows from this observation that the eddy-current loss computed on the basis of equation 6 will not be less than the actual value.

Using equation 7, the power loss per unit area of the conductor surface is

$$\frac{P}{bl} = \int_0^\infty \rho\left(\frac{\delta_x}{2\sqrt{2}}\right)^2 dx = \frac{1}{8}\rho\delta_s^2 \int_0^\infty e^{-2mx}dx = \frac{\rho\delta_s^2}{16m} \qquad (8)$$

where b and l are the width and length, respectively, of the conductor surface at which power loss P takes place, and $\delta_s/(2\sqrt{2})$ is the effective value of the current density at distance x from the surface. This equation requires 2 modifications before it can be applied to this analysis: (1) to account for the variation of the eddy-current amplitude that takes place at the frequency of the fundamental rotor current and its multiples; and (2) to account for the nonuniformity of the eddy-current amplitude on the surface of the conductor as given by figure 3.

The first of these conditions can be met approximately by assuming that the shape of the eddy-current wave is a pure sine wave, 100 per cent modulated by a fundamental-frequency sine wave given by a function

$$\delta = \delta_m \sin \omega_t t\ (1 - \sin \omega_r t)$$

ω_t being the angular velocity of the tooth ripple, and ω_r being that of the fundamental rotor current. This assumption introduces a factor into equation 8 equal to a ratio of power loss with modulated and unmodulated waves. The value of this factor is then

$$K = \frac{\dfrac{\omega_r}{2\pi}\displaystyle\int_0^{\frac{2\pi}{\omega_r}} \rho\delta_m^2 \sin^2 \omega_t t\ (1 - \sin \omega_r t)^2 dt}{\dfrac{\omega_t}{2\pi}\displaystyle\int_0^{\frac{2\pi}{\omega_t}} \rho\delta_m^2 \sin \omega_t t dt}$$

On the assumptions that the value of the ratio ω_t/ω_r is large and is an integer, both of which are reasonable since the value of ω_t/ω_r is of the order of 1,000 or greater, the value of K reduces to

$$K = 0.113/0.5$$

To overcome the difficulty caused by nonuniformity of the distribution of current density on the surface, as an approximation the distribution of the eddy-current amplitude along any normal to the bar surface may be assumed to comply with equation 7. Measurements show that the amplitude within the bar is less than that given by equation 7; hence, the actual power loss is less than that computed on the basis of equation 7. Equation 8 therefore may be written in the form

$$\frac{d\left(\dfrac{P}{l}\right)}{db} = K\frac{\rho\delta_s^2}{16m}$$

The power loss per unit length of the bar will be

$$\frac{P}{l} = \int_0^b \frac{0.113\rho\delta_{sm}^2}{0.5 \times 16m} db$$

This integral was evaluated by numerical integration, using values of δ_{sm} obtained from figure 3. The result obtained, 27 watts for all the bars in the rotor at no load, probably is greater than the true value.

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First Report of Power System Stability

The AIEE subcommittee on interconnection and stability factors* presents herein the first comprehensive review by an AIEE committee of the subject of stability, or successful parallel operation of a-c machines transmitting large blocks of power without loss of synchronism. A summary of principal installations made during the past 10 years which gives data on the various stability measures employed and a comprehensive bibliography are included.

STABILITY, in the sense employed in this report, is concerned with the successful parallel operation of a-c machines as affected by the magnitude of power transmitted. While this problem has existed since the beginning of parallel operation, it is only within the past 10 to 15 years that it has assumed a position of major concern. During this period stability has received a great deal of attention in papers before the AIEE and in the technical press. The development of analytical methods for predicting power system performance has been followed by methods for improving stability. However, during this period the general subject of stability has not been comprehensively reviewed by any AIEE committee. Hence, this "First Report on Power System Stability" has been prepared for the purpose of reviewing the developments and of summarizing in so far as appears practicable the present status of the art in this field.

Historical Review

The early problems of parallel operation were concerned principally with the phenomenon known as hunting. Prior to 1890 parallel operation of synchronous machines was accomplished in isolated instances. The problem did not assume importance until after the change from belted machines to engine-driven machines and from smooth to slotted armature construction. At about this time the necessity for parallel operation became general and the hunting problem approached serious magnitude. The cause was not well understood. It was variously ascribed to the presence of harmonic circulating currents, to the pulsating torque of the prime-movers, to the correspondence of the electro-mechanical period of the power system and the periodicity of the impulses of the prime-movers and to the improper design or functioning of prime-mover governors. Considering the complexity of these problems, particularly during the transient conditions involved in the hunting phenomena, it is not surprising that the state of the art at the time made exceedingly difficult the determination of the true cause of hunting. Probably the most successful method for minimizing hunting was the introduction of the damper winding proposed by LeBlanc in France in connection with alternators and independently by Lamme in the United States in connection with synchronous converters. Gradually the essential factors of the problem were understood and the question of harmonic circulating currents eliminated. In the first decade of the present century the problem ceased to be one of serious importance. The principal reason for this change in the situation was the introduction on a large scale of constant-torque type prime-movers in hydro-electric and steam turbines. The great increase in the size of the power systems made them inherently more stable and less subject to disturbances arising from the peculiar characteristics of an individual machine or application. However, the problem still existed in connection with special applications, such as those involving gas engine prime-movers or synchronous motor-driven compressors. It was also found that hunting was likely to be encountered with synchronous converters if the supply lines had a resistance drop of more than 15 per cent. During the last 20 years hunting has not been a serious problem considering the operation of power systems as a whole.

Another type of the general problem of parallel operation is one involving the ability to maintain synchronism both during steady-state or normal circuit conditions and during transient conditions, such as those arising from sudden increase in load, change in circuit condition, or occurrence of a short circuit with its subsequent clearing. This problem, commonly called the stability problem, is concerned with power limits and is distinct from the hunting problem which is characterized by periodic phenomena. In the early days it was recognized that synchronous and induction motors had very definite power limits. However, this was viewed as a machine problem; the corresponding system problem did not at this time receive consideration.

The methods for controlling voltage regulation were not well developed; the automatic tap changer under load, the feeder voltage regulator, the automatic generator voltage regulator, the use of synchronous condensers for voltage control were either not employed at all or not to the degree to which they are today. Consequently, the effort was directed to provide systems of good inherent regulation which was obtained generally by making lines and apparatus of low impedance. This practice to achieve good voltage regulation and the use of multiple circuits to minimize interruptions of service resulted in systems capable of transmitting relatively large amounts

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of synchronizing power with corresponding high power limits under normal operating conditions.

With the advent of the automatic voltage regulator and its application to condensers at the receiving end of long transmission lines it became possible to obtain good local regulation from a system which had high reactance and low synchronizing power. Thus it became practical to operate systems much closer to their steady-state stability limits. While this combination solved the voltage regulation problem, its exploitation in the course of time led to the transmission of large blocks of power per circuit and consequently to the stability problem.

Parallel with this development of long-distance straightaway transmission, interconnections of large power systems for economic and emergency purposes led to a different form of the stability problem. The character of the operation in this case depended very largely upon the properties of the tie line. Frequently these lines operated quite satisfactorily for steady-state conditions but in the event of a disturbance on either system, if the tie line were incapable of transmitting sufficient synchronizing power, instability would be inevitable. However, it was found that no difficulty was encountered except during severe faults if the systems were tied solidly together through tie lines designed to carry a large amount of load. Troubles were for the most part encountered on systems which were connected through fringes or through so-called "shoe string" lines. Interconnection to reduce cost and improve service reliability thus became a factor in the problem.

Concurrently, consideration was being given to the use of generator and bus reactors for the purpose of limiting the interrupting capacity required of circuit breakers. These layouts also affect system stability by decreasing the synchronizing power under conditions before and after the fault is cleared and by reducing the severity of the disturbances themselves during the fault condition.

About 1920 the work on the power circle diagram in connection with long distance power transmission focused attention to the margin of power between the operating point and the theoretical stability limit. This led to exhaustive tests, both in the laboratory and in the field, for establishing the characteristics of power systems under steady-state conditions and during transient disturbances. In 1925 a case of instability occurred on a long-distance high-capacity transmission system in which the system was operating under steady-state conditions while portions of the paralleling line were out of service for maintenance and repair. While the possibility of pull-out had been recognized before this experience, its occurrence nevertheless did stimulate further careful investigation of stability limits of long transmission systems. As a result of the interest in the subject and the development in the methods of calculating electrical systems, it was found that system oscillations during disturbances could be predicted with satisfactory accuracy by step-by-step methods. This has been substantiated by the data on power system oscillations obtained during (1) scheduled tests and (2) normal operation by means of automatic transient recording apparatus.

Attention was then directed toward methods for improving system stability including consideration of the power system layout and operation as well as features of the apparatus. As a result of this work a number of important changes in practice came about, concerning particularly the reactance of synchronous machines, the speed of response of excitation systems, and characteristics of automatic voltage regulators. The most successful modification of practice in order to improve stability has been the recent developments of high-speed circuit breakers and relays. Consideration has also been given to the control of all factors in the problem with a view to co-ordinating them to give the maximum improvement in stability at a minimum cost.

Methods of Analysis

Parallel with the recognition of the importance of the stability problem the necessity arose for the development of methods for calculation. Thus about 1922 engineers seriously undertook to determine the stability limits of power systems; they set about the task of predicting the time variation of angle, power, and voltage quantities for all types of transient disturbances. Prior to this time the basic ideas relating the power, angle, and voltages of simple systems were understood but it was necessary to extend these basic concepts for the more complicated problems under consideration. An example of these extensions is the power circle diagram which was developed to include distributed capacity and general networks. The analytical work back of the circle diagram was extended, covering not only the case of 2 machines but 4 or more machine cases for which the circle diagram is not applicable.

The power circle diagram was early found to be of considerable value in pointing out maximum power limits and requirements in reactive kilovolt-amperes to maintain system voltages. It was also helpful in obtaining power-angle relations between 2 ends of a long line, particularly between points of maintained voltage.

Since the stability problem is so closely related to the characteristics of machines the next development was the extension of the Blondel 2-reaction method to include the transient performance of machines with salient-pole rotor construction.

Undoubtedly the most important analytical development in the general field of unbalanced polyphase problems is that of "symmetrical components." Applied to the stability problem, it became possible to calculate the distribution of current and voltage throughout the system during periods of unbalanced faults and also to determine the equivalent balanced positive-sequence impedance that should be placed at the point of fault to completely simulate in its action upon machine performance the particular unbalanced fault. In this connection it was necessary to develop methods of calculation and of test for the phase-sequence constants of lines and apparatus.

An interesting development of this period was the mechanical analogue, a mechanical equivalent of the actual electro-mechanical system, in which the principal generating units are replaced by small flywheels and the

system reactances by springs. By properly proportioning the elements of this system the angle-time variation of this equivalent will exactly duplicate the system performance quantitatively as well as qualitatively, thus indicating stability or instability for different kinds of faults. While the mechanical analogue has been used to some extent for the purpose of calculating system performance, its principal value has been its unique facility for visualizing the essential factors in the stability problem.

A very tedious and irksome part of the early stability calculations was the reduction of the actual system into an approximately equivalent network of a more manageable form, such as 2- or 3-machine problem. The construction and use of the network analyzer or a-c calculating board has eliminated much of this labor. By means of the a-c calculating board the entire system impedance diagram including the generating sources can be set up, thus representing in miniature the equivalent of the actual system. From this duplicate system the necessary constants may be obtained which will reduce a given system to the simplest number of impedance branches. The problem may be solved by a step-by-step method, either analytically or by the calculating board, using small intervals of time and adjusting by steps the phase position and magnitudes of the machine voltages as dictated by the simultaneous solution, considering the acceleration and inertia of all the machines. Mention should also be made of the integraph which has been employed in the production of general curves which have been used in the solution of specific stability problems.

The development of automatic recording equipment has provided an important source of information on power system performance. This equipment, which is of the oscillographic type, is capable of recording instantaneous variations in voltage, current, power, and phase angle quantities—including both phase quantities and their sequence components. The data obtained in this manner are useful in determining the margins in stability under operating conditions. These records are valuable in checking relay and circuit-breaker performance, and also in determining the character and location of the fault.

The most recent development affecting methods of analysis has to do with the determination of the machine constants to be used. It has been shown that saturation affects transient reactance and also certain other reactances used in transient stability calculations. Recently, work has also been done toward the determination of the appropriate values of reactance to use in steady-state stability calculations. The results of this work are being reviewed by a subcommittee of the AIEE electrical machinery committee.

In summarizing this review of the methods of analysis, it can be stated that the available methods are now considered to be satisfactory for determining the stability of a system under any assumed set of conditions. It is recognized, however, that for certain types of systems the present methods require analysis by a relatively large number of independent machines and this requires a considerable amount of work to cover a reasonable range of operating conditions.

General Discussion of Factors Affecting Stability

In this report the stability terms are used in accordance with the following definitions:*

"Stability, when used with reference to a power system, is that quality of the system or part of the system which enables it to develop restoring forces between these elements equal to or greater than the disturbing forces so as to restore a state of equilibrium between the elements.

"Steady-state stability exists in a power system if it operates with stability when there is no aperiodic disturbance on the system.

"Transient stability exists in a power system if, after an aperiodic disturbance has taken place, the system regains steady-state stability.

"If automatic devices are used to aid stability their use should be indicated by the following phrases:

Steady-state stability with automatic devices.

Transient stability with automatic devices.

"The term, automatic devices, includes only those devices which are operating to increase stability during the period preceding and following a disturbance as well as during the disturbance. Thus relays and circuit breakers are excluded from this classification and all forms of voltage regulators included. Devices for inserting and removing shunt or series impedance may or may not come within this classification depending upon whether or not they are operating during the periods preceding and following the disturbance."

These definitions of stability terms recognize a distinction between stability with automatic devices, and stability by inherent action. While the general term includes both effects, it is the intention that mention should be made of automatic devices when used.

It is recognized that the definitions of stability are based upon viewing the problem as essentially one of equilibrium. In each synchronous machine there is a problem of equilibrium between the mechanical forces acting on machine shafts and the electrical forces acting on the machine windings. Thus in the synchronous generator there are the mechanical forces due to the prime-mover tending to accelerate the rotor and the electrical forces due to electrical output and losses tending to decelerate the rotor. In the synchronous motor there is the corresponding problem of equilibrium between the electrical input and the mechanical output and losses. If, in the process of maintaining equilibrium, synchronism is not lost, stability results.

The factors affecting the stability problem, therefore, include any which will affect the mechanical input (or output) and the electrical output (or input). Among the mechanical factors are the prime-mover input, the governor characteristics and inertia of rotating parts, and among the electrical factors are the characteristics of circuits including switching operations and apparatus including excitation systems and their voltage regulators, and load circuits including induction motors as well as static apparatus.

The above discussion indicates that there are many factors entering into the stability problem. Also, there are many ways in which these factors may be controlled to secure stability. The extent to which any of these

* These definitions are taken from the report of the subject committee on definitions of terms used in power system studies, presented at the AIEE winter convention, New York, N. Y., January 22, 1932.

factors are beneficial in improving stability is dependent upon the particular system under consideration.

This report is principally concerned with stability as affecting the operation of synchronous machines, such as a combination of a generator and a motor or 2 groups of synchronous generators with an intervening transmission line. The report is also principally concerned with the usual type of power system where parallel circuits are employed and a relatively high standard of service is required.

In general, the transient stability limit of a system is considerably lower than the steady-state stability limit. Hence, the transient stability limit is more important for the service and layout conditions normally encountered. In general, the basis of system design from the stability standpoint is predicated on the successful clearing of a particular type of fault in any line section. The type of fault considered is usually the double line-to-ground fault on transmission systems. However, single line-to-ground faults are sometimes considered for transmission systems and 3-phase faults for metropolitan systems. In a few situations single-circuit lines may be employed because service conditions permit the interruption of supply to the load or because the system layout is such as to permit the loss of an entire station output. In these situations the steady-state stability limit, of course, becomes of greater importance. However, even in such cases secondary circuit faults or abrupt load changes are likely to make the controlling stability limit a transient limit.

Discussion of Specific Factors in the Stability Problem

A discussion will now be made of the effect of various specific factors in the stability problem. For convenience these will be arranged under 2 principal headings of (1) power system layout and operation and (2) characteristics of apparatus.

Power System Layout and Operation

The stability characteristics of power system layouts should be analyzed for the 3 circuit conditions associated with the fault, *viz.:*

1. Before the fault.
2. During the fault.
3. After the fault.

Some features of layout are beneficial to stability for all 3 circuit conditions while other features are beneficial for one condition and detrimental for another; hence, the many features of power system layout must be weighed individually in connection with each circuit condition.

Series Reactance

The most obvious method of increasing the stability limit of a system is to reduce the transfer reactance or "through reactance" between synchronous machines as this directly increases the synchronizing power that may be interchanged between them. The reactance of a transmission line may be reduced by reducing the conductor spacing. Usually, however, the spacing is controlled by other features, such as lightning protection and minimum clearance to prevent an arc from one phase involving another phase. Another method of reducing line reactance is to increase the conductor diameter by using material of low conductivity or by hollow cores. Usually, however, the characteristics of the conductors are fixed by economic conditions quite apart from stability. The split-conductor has been considered for a number of cases as a measure for decreasing line reactance but objections from a mechanical point of view have prevented its use on any major project.

The transformer reactance should be kept as low as practical. While some variation from normal reactance is permissible, economic considerations usually prevent much departure from the normal value.

The series capacitor provides another means for decreasing the "series" reactance of transmission systems. However, at times of system faults the current through the capacitor raises the voltage across it to a value much in excess of its normal value. Hence, to protect the capacitor against puncture the usual practice is to use a normal voltage capacitor with means to short circuit it during excess current conditions. The series capacitor as proposed is thus rendered ineffective at just the time when it is most desired. The alternative is to use capacitors capable of withstanding the high voltages arising under fault conditions. In no major project in America has the series capacitor received serious consideration.

The usual ways of reducing transmission circuit reactance drops are to use additional parallel lines or circuits of higher voltage. Comparisons at times are made

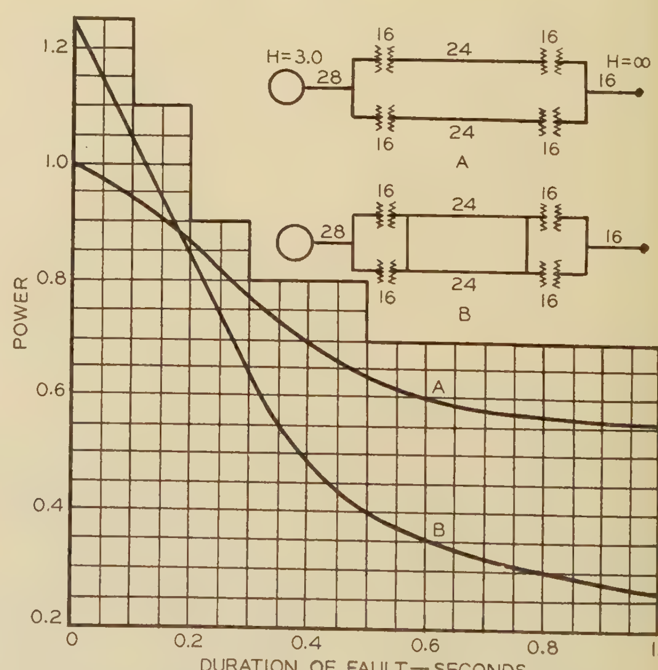


Fig. 1. Effect of bussing arrangement on stability limits; double line-to-ground fault at sending end

A—Low-voltage bussing *B*—High-voltage bussing
System reactance shown in per cent; inertia constant *H* = kilowatt-seconds/kilovolt-ampere

between a larger number of low voltage circuits and a small number of high voltage circuits. In these cases it must be borne in mind that the switching out of a circuit produces a relatively greater reduction in the power limit of the layout with the smaller number of circuits than with the larger number.

Bussing Arrangements

The method of paralleling lines or apparatus, or the bussing arrangements, may have an important bearing on system stability. The use of high-voltage busses at the ends of transmission lines or at intermediate points results in smaller reduction in the "through reactance" at the time of the isolation of a faulted transmission line section than for the case with low-voltage bussing, since the latter involves the loss not only of the line but also of the associated transformers. During the faulted condition the shock to the system is greater with the high-voltage bus than with a low-voltage bus. It is impossible to generalize on the relative merits of high- and low-

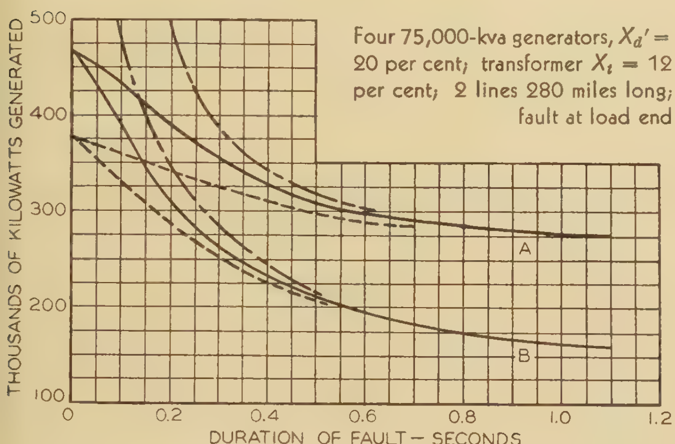


Fig. 2. Effect of number of switching stations on stability limit

A—Single line-to-ground fault
B—Double line-to-ground fault
- - - - - One intermediate station
——— Two intermediate stations
— - — Bus fault cleared with no loss of line

voltage bussing arrangements as the result in any particular case is dependent upon the relative reactance proportions of the system, the type and duration of the fault, and the character of system grounding. The results of calculations on a particular system with alternative bussing arrangements are illustrated in figure 1. It will be observed that for the faults of short duration the change in the "through impedance" of the system after the fault is cleared is more important than the shock to the system during the fault, and, therefore, the high-voltage bussing arrangement gives higher stability limits; while for faults of longer duration, the shock to the system is more important and the converse regarding layout is true. By using reactors between the high-voltage busses, it is possible to obtain characteristics intermediate be-

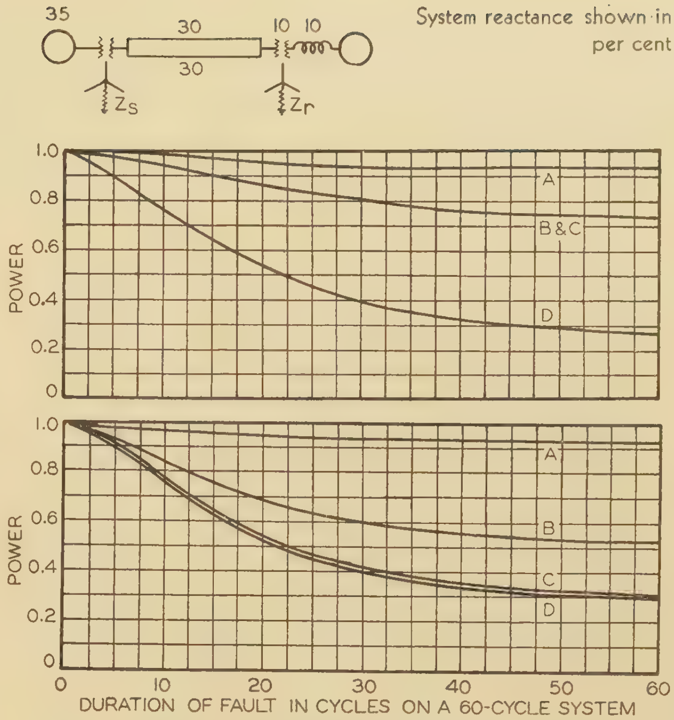


Fig. 3. Effect of grounding methods upon system stability

Curve	Kind of Fault	Z_s, Per Cent	Z_r, Per Cent
A	Single line-to-ground	13	+j10
B	Double line-to-ground	13	+j10
C	Double line-to-ground	13	0
D	Double line-to-ground	0	0

Upper set of curves for fault on high-voltage bus at sending end
Lower set of curves for fault on high-voltage bus at receiving end

tween those for high- and low-voltage bussing, approaching either to any degree desired. Figure 2 shows the results of the study in a particular case of the effect of varying the number of intermediate switching stations on a long transmission line.

Another method of bussing is incorporated in the scheme known as "synchronizing at the load" as applied to metropolitan type power systems. By metropolitan system is meant the type of system that exists in large cities and is characterized by large turbogenerating units located close together with short transmission distances. With this scheme there are no direct ties between synchronous machine busses but only indirect ties through a multiplicity of connections at secondary or utilization voltages. With this layout secondary faults will not have a severe effect upon the system and can be "burned clear." Faults on a particular generator bus will require disconnection of that unit but the remaining units while subjected to a substantially greater shock, will accelerate or decelerate as a unit. Of course, the shock to the connected load will be decreased as the speed of circuit breakers and relays is increased.

While "synchronizing at the load" was developed for supplying power to metropolitan areas, the underlying general principle has been considered in connection with long-distance transmission projects. The modification of the scheme for this application is characterized by the

bussing of the system only on the low-voltage side at the receiving end. On such a system transmission-line faults result in the disconnection of an entire unit consisting of a generator, sending transformer, transmission line, and receiving transformer. Since the plan of operation contemplates the disconnection of a unit for every fault on

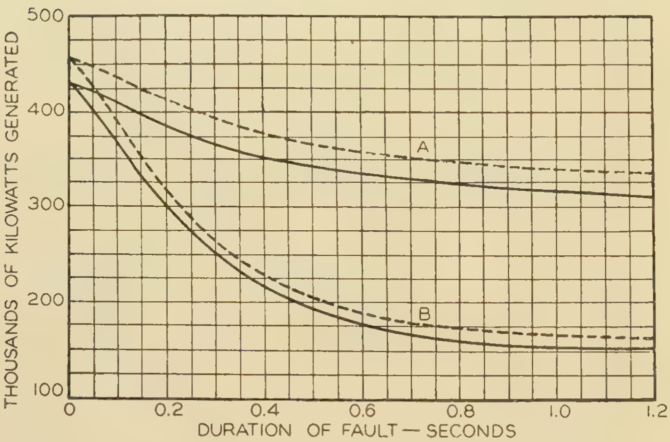


Fig. 4. Effect of generator reactance upon stability

A—Single line-to-ground fault
B—Double line-to-ground fault

Solid curves for generator transient reactance $X_d' = 30$ per cent; broken curves for $X_d' = 21$ per cent

Fault at load end; 2 lines, 280 miles, 3 sections; transformer $X_t = 10$ per cent; 4 70,000-kva generators

the transmission line or its associated apparatus, each circuit may be operated relatively close to its steady-state power limit. Faults on the low-voltage bus at the receiving end will probably be controlling in determining the transient power limits. These connections are similar to those employed on early systems where transmission lines from separate hydroelectric plants were paralleled only at the receiver.

The same general principles of system connection have also been employed in circuits employing 2-winding generators and 4-winding transformers. These schemes improve stability by limiting the severity of short circuit and by distributing the stress among the remaining units. An important advantage of the double-winding generator arises from the fact that in the event of a fault on one winding the sound winding can carry load and thus minimize the disturbance to the system which would result from the disconnection of the faulted machine and the readjustment of load on the remaining units.

Another method of bussing is the "loose-linked" system which consists of a number of power areas normally operated in parallel, being loosely connected for purposes of synchronizing and interchange of power. The plan of operation is such that in any power area the largest generator or the interlinking ties may be lost without leaving a load in an area in excess of the ability to carry it. In the event of a serious disturbance within a power area, that area including its load and sources of power is isolated from other power areas by opening of the ties at appropriate points.

Grounding

In America it is common practice on high voltage systems to ground the neutral solidly and on moderate-voltage systems to ground the neutral solidly or through a resistance. For certain types of high-voltage systems there has been recently an increase in the tendency to provide transformers with sufficient insulation in the neutral to permit grounding through a moderate impedance. The Petersen scheme of power system grounding using reactors tuned with the capacitance to ground at fundamental frequency has not been generally accepted though it has been used successfully in a few locations. These schemes also have arc-suppression characteristics as discussed in a subsequent section. The introduction of neutral impedances, by limiting the severity of the fault, increases the stability limits. Two effects may be present. If the impedance is a pure reactance, the current is limited and the synchronizing power is increased thereby; if the impedance is a resistance, power is absorbed in it and the generator output increased and its acceleration is correspondingly retarded. The effects of these factors are illustrated in figure 3, which shows the stability limit as

Table I—Normal Design Values of Reactance Constants of Synchronous Machines

	Reactance, Per Cent				
	Synchronous*				
	Direct Axis X_d	Quadrature Axis X_q	Transient** X_d'	Subtransient† X_d''	Negative-Sequence† X_2
Turbogenerators					
2 pole	110	107	14	9	9
4 pole	110	108	23	14	14
Salient pole generators and motors with dampers	100	65	35	24	24
Salient pole generator without damper	100	65	35	32	45
Synchronous condensers	160	100	40	28	24

* Unsaturated values. ** Rated current values. † Short circuit values

Table II—Inertia Constants of Synchronous Machines and Acceleration Formula

Type	Inertia Constant H*
Turbogenerators	See figure 7*a*
Waterwheel generators	See figure 7*b*
Synchronous condensers**	
Large	1.25
Small	1.00
Synchronous motors	2.00

$$* \; H = \frac{\text{kw sec}}{\text{kva}} = \frac{0.231(WR^2)(RPM)^2 \times 10^{-6}}{\text{kva}}$$

** Hydrogen cooled, 25 per cent less

Acceleration Formula

$$\alpha = \frac{180 f \Delta P}{\text{kva } H}$$

α = acceleration (or deceleration) in electrical degrees per second per second
f = frequency
ΔP = kilowatts available for acceleration (or deceleration)
WR^2 = moment of inertia in pounds per foot²

a function of the duration of the fault and the connection of the neutral impedance for single and double line-to-ground faults on the high-voltage line at both the sending and receiving ends of a typical system. These curves show conclusively that neutral impedances, preferably resistance at the sending end and reactance at the receiving end, are beneficial in maintaining stability. The importance of the method of grounding in relation to power system stability has been minimized by the development of high-speed breakers and relays and the trend in the direction of basing system design upon the more severe types of faults. In general, however, factors such as lightning protection and relaying, and cost affected by insulation and interconnection with other systems, rather than stability, determine particular methods of grounding to be employed.

Power System Operation

Power system operation is often as great a factor as proper system design to insure system stability. The allocation of generator capacity in relation to the system load and circuit conditions is of considerable importance, particularly under abnormal circuit conditions. The stability problem may be accentuated by interconnection and is complicated by the related problems which arise when frequency control is applied or when the location of generating capacity is determined by maximum economy requirements rather than system load requirements.

Most power systems are designed for adequate stability under steady-state conditions. There are, however, many systems where a stability problem is encountered as a result of a fault and for economic reasons it is not always possible to eliminate this condition.

A consideration of certain basic operating principles will prevent exceeding the steady-state limits and insure prompt recovery following a fault.

Adequate spinning reserve capacity either in the form

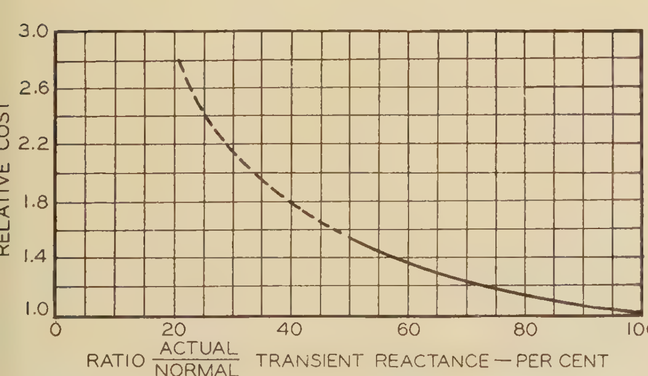


Fig. 5. Approximate cost of decreasing the transient reactance of salient-pole synchronous generators

of spare generators or reliable interconnections must be available in each load area to insure a steady-state limit in excess of the power and reactive kilovolt-ampere requirements in event of loss of a generating unit or loss of excitation.

The method of supplying excitation to a system has an important effect on stability. The choice of the value of bus voltages to be maintained or compensated for load and circuit changes may be of great importance. Voltage regulators tend to improve stability conditions by auto-

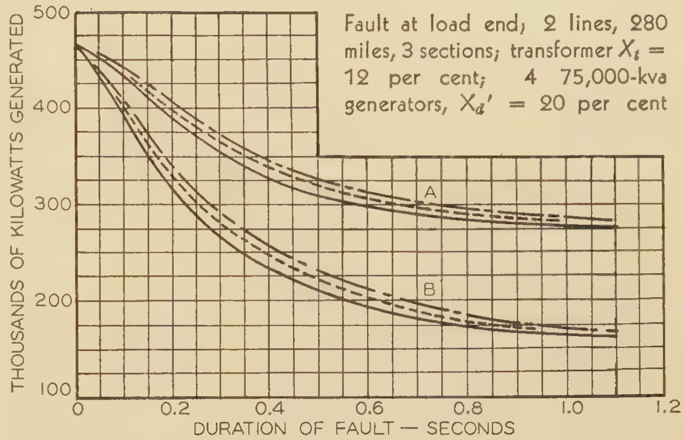


Fig. 6. Effect of generator inertia upon system stability

A—Single line-to-ground fault
B—Double line-to-ground fault

——— Minimum WR^2 (31×10^6 pound-feet²)
- - - - - 50 per cent additional WR^2
— - — 100 per cent additional WR^2

matically changing the excitation in accordance with loads. They are capable of sustaining system voltages within safe limits for the loss of excitation on one of the units. They also tend to keep the field strength of individual units within reasonable limits, thereby preventing the cascading of trouble following the initial disturbance. Other characteristics of excitation systems and their control in relation to stability are discussed in a subsequent section.

The increasing use of automatic devices, such as refrigerators, water heaters, water pumps, etc., which are not locked out following an outage, results in excess power requirements when service is restored. A recent outage resulted in a peak following restoration of service which was approximately 45 per cent in excess of the load interrupted.

Provision must be made for excess generator capacity for a short period following restoration of service or the service restored slowly to limit the temporary load until its diversity becomes normal.

The spinning reserve capacity for best results should be distributed in the several load areas so that its availability is not restricted by tie-line limitations.

The use of automatic load control on interconnecting tie lines has increased the practical load limits of these lines by preventing the usual drift in the tie-line load, thereby holding the scheduled load well below the tie-line limits. These devices are of no value for transient conditions.

Co-ordination of stability studies and operating instructions for abnormal conditions is a matter of considerable importance for insuring the maintenance of stability or avoidance of service interruption.

When synchronism is lost on a system having synchronous condensers, a state of equilibrium may be reached under which the system will neither accelerate nor retard until conditions are changed by switching operations, or by removal of synchronous condensers. The removal of synchronous condensers, either manually or by underspeed relays, relieves the system of superimposed low frequencies, due to condenser excitation, and permits a more rapid restoration of service.

Characteristics of Apparatus

Synchronous Machines

The characteristics of synchronous machines which are important from the standpoint of stability are substantially the same in the generator, motor, or condenser. In general, the characteristics of generators are of much more importance because they constitute the largest percentage of the total connected synchronous capacity and because they have such an important bearing on the overall system angles. The following discussion will be given in terms of synchronous generators with the understanding that for synchronous condensers and motors the general features are the same but generally of relatively less importance.

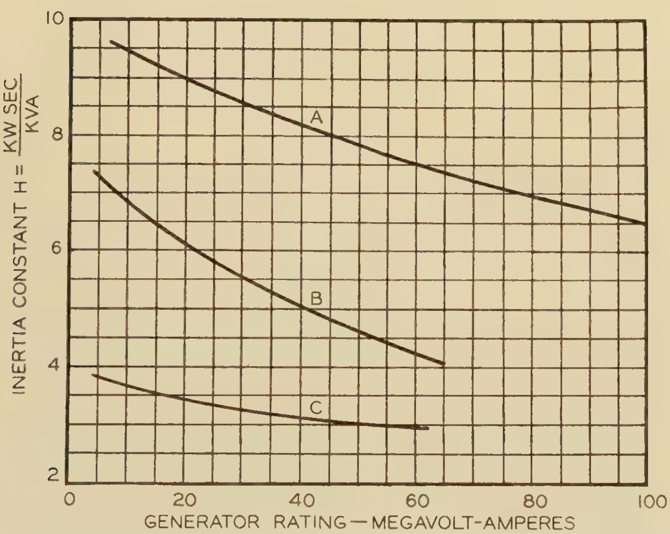


Fig. 7a. Inertia constants of large turbogenerators, turbine included

A—1,800 rpm condensing
B—3,600 rpm condensing
C—3,600 rpm noncondensing

The best criterion of generator performance under conditions in which system stability is determined chiefly by the transient characteristics is its transient reactance or more definitely, the direct axis component commonly designated as X_d'. The value of this reactance is affected to some extent by the saturation characteristics of the machine. The appropriate value to be used in a stability analysis also varies with the location and severity of the fault. From the standpoint of calculation it is usually impracticable to consider more than one value of transient reactance, which value should be selected considering the condition both during the fault and immediately after its isolation. The effect of decreasing the transient reactance of generators upon increasing the stability limits for a particular study is shown in the curve of figure 4. The normal values of the constants of various types of synchronous machines are shown in table I. The effect of decreasing the transient reactance upon the cost of a machine is indicated in a general way by the curves of figure 5. In a number of installations it has been found desirable to employ generators of less than normal transient reactance.

For a few present-day systems, steady-state stability limits will be found important. With increased application of faster breakers and relays and the logical attempt to increase the load carried on these circuits, the steady-state stability limitations will become increasingly important. The best criterion of machine performance with reference to steady-state stability is equivalent synchronous reactance. This reactance differs from the ordinary synchronous reactance defined by the AIEE since it has been adjusted for the operating conditions in order to include the effects of saturation according to the load currents and excitation requirements.

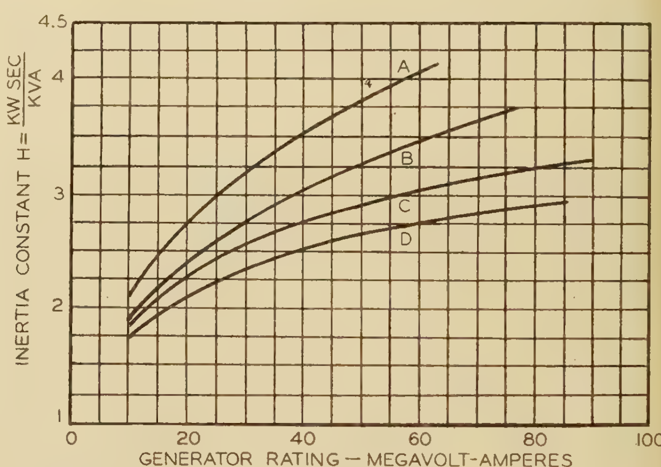


Fig. 7b. Inertia constants of large vertical-type water-wheel generators, including allowance of 15 per cent for water-wheels

A—450–514 rpm
B—200–400 rpm
C—138–180 rpm
D— 80–120 rpm

Short-circuit ratio is in itself not directly a measure of the characteristics of the machine from the standpoint of stability. It is, however, of value as an approximate measure of the size of machine. Its value in this case depends upon the fact that to a considerable extent any reduction of reactance in a machine below its normal value is obtained by derating a larger machine and modi-

ing the current-carrying parts to meet the reduced
lues.

The inertia of a synchronous generator or motor is also factor in the stability problem since it affects the natural riod of system oscillation, or the time required to reach point beyond which recovery would be impossible. gure 6 shows the results of calculation for various values generator inertia upon the stability limits for a parcular system. The normal values of inertia constants the various types of synchronous machines are indited in table II. The curves of figure 7 show the inertia nstants for steam turbine generators and vertical waterheel generators. The effect of increasing the inertia of nerators upon the cost is illustrated by the curves of

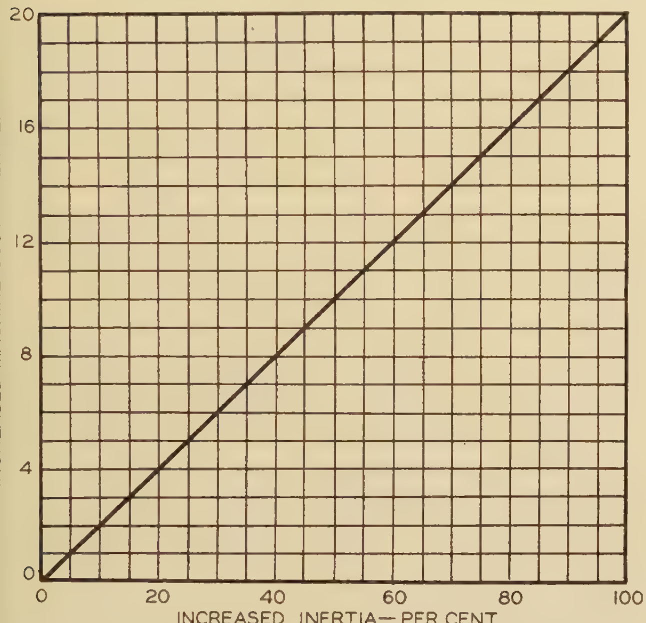


Fig. 8. Approximate cost of increasing the inertia of large vertical-type water-wheel generators

gure 8. In a few cases, where calculations have indited that a particular system would operate relatively ose to the stability limits, generators of higher than ormal inertia have been installed.

The severity of unsymmetrical system faults is affected the negative-sequence impedance of the connected achines. Amortisseurs or damper windings affect both e real and reactive components of this impedance. achines without damper windings possess the highest gative-sequence reactance and from this viewpoint are e most desirable but on the other hand machines with gh-resistance damper windings possess the highest gative-sequence resistance. The curves in figure 9 ow the combined effect of the damper material upon e stability limit of a typical system for line-to-line and uble line-to-ground faults on the high-voltage bus at e generator end. It will be observed that the improveent with high-resistance dampers is quite appreciable r faults of long duration but for faults of a duration mparable with that which can be obtained at present with high-speed breakers, the improvement is very much less. In the event of system oscillations low-resistance copper damper windings produce the greatest damping of the mechanical movement. However, this effect is unimportant during and following a system fault except in the rather rare case in which the system is so constituted that pull-out takes place as a result of compound oscillations following a disturbance. To obtain the partial

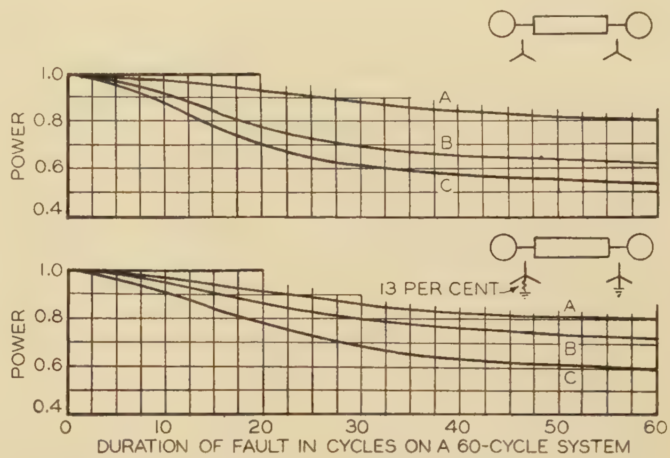


Fig. 9. Effect of damper winding material upon stability limits

System same as figure 3C

A—High resistance *B*—No dampers *C*—Copper
Upper curves for line-to-line fault
Lower curves for double line-to-ground fault

advantage of the high loss associated with high-resistance dampers at times of unbalanced faults and the damping of oscillations associated with low-resistance dampers, the generators for one installation were supplied with a new type of damper winding which consists of a double cage arrangement in which the outer row of bars is made of high-resistance material and the inner row of bars is made of a low-resistance material imbedded in the iron. For the double frequency associated with negative-sequence the copper bars possess a high reactance and, therefore, force most of the current through the high-resistance bars, but for the low-frequency associated with the system oscillations the current varies inversely with the resistance of the damper bars in which case most of the current flows through the copper winding. The benefits from high-resistance damper windings will be decreased as the fault duration is decreased by the use of faster breakers and relays. Damper windings also have characteristics which tend to suppress spontaneous hunting and to reduce system voltages and recovery rates arising from short circuits; in these respects, low-resistance copper dampers are somewhat more effective than high-resistance dampers.

With the increase in size of generator units, the greater concentration of power on a single bus has increased the duty on circuit breakers and the area affected by a fault on or near the bus. These effects have been greatly

minimized by the advent of the 2-winding generators in which the 2 armature windings are connected only through their mutual coupling which may be controlled by suitable design. Generators of this character lend themselves to incorporation as units in the system layout known as "synchronizing at the load" or its variations as described previously.

Excitation Systems

Control of the excitation system on synchronous machines provides a means for improving stability limits for transient conditions and also for steady-state conditions. Such systems operate to increase stability, (1) by overcoming partially the demagnetizing effect within a machine or (2) by positively increasing the machine fluxes and terminal voltages. Excitation systems that are effective from the standpoint of stability are commonly termed quick-response excitation systems, the principal features of which are:

1. Exciter of high rate of build up and of high "ceiling" voltage.
2. A reliable source of power to the exciter.
3. Quick-responding regulator.

Exciter response is the rate of build up or build down of the main exciter voltage when resistance is suddenly removed from or inserted in the main exciter field circuit by the action of the voltage regulator. The response of an exciter may be expressed as either volts per second or the ratio of the volts per second to some other designated value, e.g., the nominal collector ring voltage. In order to obtain the benefits of a high rate of response, it is necessary for the exciter to have a high ceiling voltage, i.e., a high ratio of maximum to normal operating voltage. The actual response depends upon the excitation system as a unit, on the initial value of the exciter voltage, and on the characteristics of the field and armature circuits of the main machine, and in general varies appreciably during the build-up and build-down process. Because of this variation, it has been found desirable to establish a definite basis for discussion, guarantees, and tests as defined under nominal exciter response.

The nominal exciter response is defined as the ratio to the nominal collector ring voltage of the slope, in volts per second, of that straight line voltage-time curve which begins at nominal collector ring voltage and continues for one-half second, under which the area is the same as under the no-load voltage time build-up curve of the exciter starting at the same initial voltage, and continuing for the same length of time.

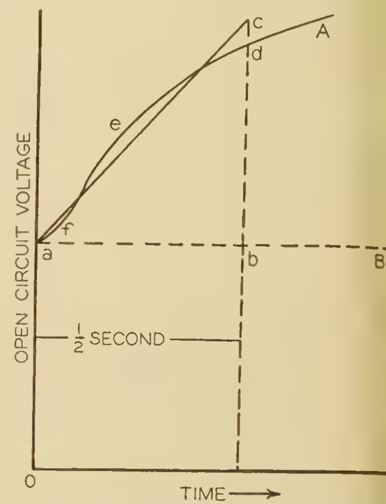
Note: Nominal collector ring voltage is the voltage across the collector rings required to generate rated kilovolt-amperes in the main machine, at rated voltage, speed, frequency, and power factor with the field winding at a temperature of 75 degrees centigrade.

Figure 10 illustrates how exciter response is determined.

The exciters for quick-response excitation systems are built so that the field circuits have low time constants usually obtained by subdividing the fields and using external resistances in series with them together with other changes in design proportions. Generally, it is found most practicable to provide a pilot exciter operating with resistance in series with the field circuits of the main exciter so that the short-circuiting of these resistances will quickly apply increased voltage to the main machine field. This combination is of further advantage in eliminating the necessity for main field rheostats. The require-

Fig. 10. Determination of nominal exciter response

A—Actual build-up curve
B—Nominal collector-ring voltage
Area *abc* = area *afedb*



$$\text{Nominal response} = \frac{\text{slope of straight line } ac \text{ in volts per second}}{\text{nominal collector-ring voltage}} = \frac{2bc}{Oa}$$

ment for a high ceiling voltage makes it necessary to supply exciters of more liberal design than was the case with slow-response excitation systems heretofore in common use. With quick-response excitation systems it is more important than with previous excitation systems to have a reliable source of power for the exciter, sufficiently ample to supply the heavy demands that are required when a fault occurs.

The voltage regulator characteristics desirable with quick-response excitation systems do not differ radically from some of the types heretofore available. The principal feature of the new regulator has been the introduction of means which make the regulator respond to a sort of average voltage of the different phases instead of from a single phase which was prior practice. This change was made because of the fact that on the occurrence of certain types of unbalanced faults the voltage of a particular phase may rise though the voltage on the remaining phases drops. Thus the old type of regulator connected to this phase would introduce a change in the excitation in the wrong direction from the standpoint of system stability. This feature has been incorporated in commercial regulators in several different forms operating from different quantities. The original form used a network for supplying positive-sequence voltage to the regulator. Subsequently, this result was approximated by the substitution of a torque motor, a polyphase motor which develops a torque proportional to the difference of the squares of the positive- and negative-sequence voltages. More recently rectifying means giving the average of the 3 phase-voltages have been employed to give corresponding action.

Quick-response excitation systems today are commonly

ontrolled by the exciter rheostatic type regulator pro-
ided with special auxiliary means for momentarily in-
reasing the excitation in case a severe system disturbance s indicated. The exciter rheostatic regulator has the dvantage over the vibrating type of being "at rest" for a large percentage of the time in comparison with the ibrating type, which principle will result in reduced naintenance.

Quick-response excitation systems tend to improve stability limits of power systems in 3 ways.

1. Maintaining or increasing machine flux against demagnetizing action of fault currents.

2. Supplying deficiency in system excitation due to loss of other sources of excitation.

3. Increasing steady-state stability limits.

Quick-response excitation provided one of the earliest methods used for improving the transient stability limits of systems. Its importance in this respect has, however, been minimized by the developments of high-speed circuit

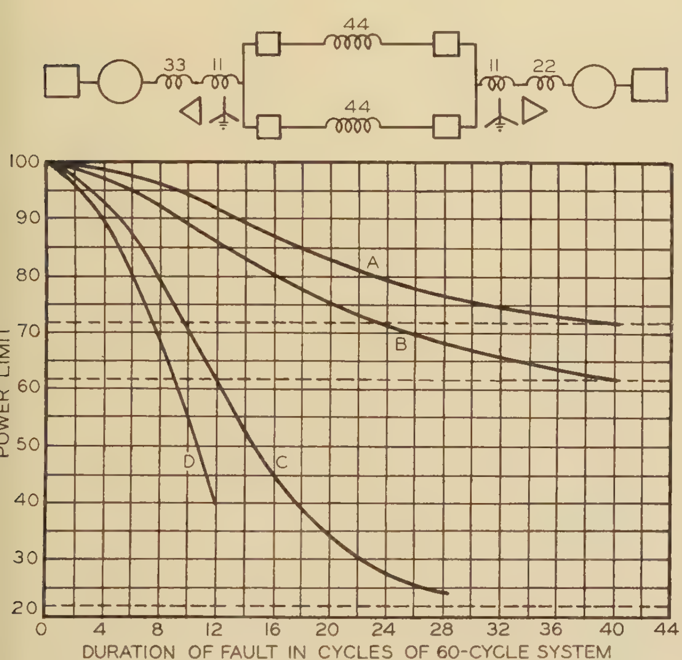


Fig. 11. Effect of duration of fault on power limits for different kinds of faults

A—Single line-to-ground fault
B—Line-to-line fault
C—Double line-to-ground fault
D—Three-phase fault

System reactance shown in per cent

breakers and relays which limit the duration of fault currents and their demagnetizing effects.

Another feature of quick-response excitation systems is the ability to increase the excitation to meet the requirements of a system arising from the loss of other sources of excitation as from the disconnection of a generator or condenser. This feature cannot, of course, be supplied by means of high-speed circuit breakers. In order to be effective in this respect a quick-response excitation system must have a relatively high ratio of ceiling to normal operating voltage and the regulating equipment must be such as to permit operation under these conditions for the length of time necessary for some readjustment in the system to be brought about.

Quick-response excitation systems also provide means for increasing the steady-state stability limits. Laboratory tests on miniature systems have indicated that quite large increases in the steady-state limits over the values possible with fixed excitation can be secured by the application of a suitable regulator and exciter. These increases vary from 300 per cent for a generator and a synchronous motor directly connected down to 25 per cent for the condition simulating the transmission power over a 200-mile line at 220 kv. The effect of the excitation system in this connection may be viewed as tending to make the steady-state stability limits depend upon transient instead of synchronous reactances. In general, however, since the steady-state limits are higher than the transient limits the use of a regulator to increase the steady-state limits has been without real significance. There is also a question as to the desirability of having the operation of a station at its rated load being dependent upon the functioning of a regulator. Consequently, the choice of regulator has been determined from its performance under transient conditions and its maintenance under ordinary operation. In these respects the exciter rheostatic regulator possesses advantage over the vibrating type though the latter would appear to be superior in improving dynamic steady-state limits.

High-Speed Circuit Breakers and Relays

The duration of a fault condition has a very important effect on the stability of a system. The fault condition reduces synchronizing power (1) directly by altering the equivalent circuit constants and (2) indirectly by reducing the effective machine voltages through the demagnetizing action of fault currents. The stability limits as affected by the speed of breaker and relay operation vary through a wide range from (1) the limits corresponding to sustained faults to (2) a mere switching operation assuming extremely fast fault isolation. High-speed circuit breakers and relays are capable of covering most of this range and thus constitute a very important measure for increasing the stability limits, particularly for transmission systems.

The relation between the speed of fault isolation and the transient stability limits for a typical transmission system is indicated in figure 11 which also gives the impedance constants of the various system elements. The system is assumed to be subjected to a fault on one line near the high-voltage bus at the sending end and is cleared by the opening of the 2 breakers simultaneously. The curves assume hydroelectric-type generators, and receiving-end machines of relatively high inertia. The calculations were made for the 4 different types of faults shown on the curves, which are plotted in terms of the time required for the isolation of the fault and the ratio of the power that can be transmitted to the power limit corresponding to the switching out of one section of the transmission line. The dotted lines show the loads which can be carried with sustained short circuits of the various

types assuming quick-response excitation systems capable of preventing demagnetization of the machines.

The curves in figure 11 just discussed apply to a system subjected to a fault at the sending end. The relative stability conditions for the fault at sending and receiving ends of a somewhat different system were given in figure 3 which has been discussed previously in connection with the use of neutral impedances. It will be noted that a moderate value of neutral resistance at the sending end may make the fault at the receiving end on a grounded neutral system relatively more severe than at the sending end. However, the gains in stability due to the use of high-speed circuit breakers are of the same order for faults at the sending or receiving ends of the transmission system.

On metropolitan type systems the permissible time for isolating the fault will be relatively longer than for transmission systems since the latter are usually operated closer to the stability limits. Thus in the metropolitan systems it is possible to introduce reactance in the system in such a way as to limit the duty on circuit breakers. This problem can conveniently be studied by means of curves characteristic of the type of system equivalent to the "2-machine problem" using reactances as defined in the insert on figure 12. These curves indicate that by taking advantage of the faster speeds made possible by the recent developments of circuit breakers, increased amounts of reactance may be introduced in the system which may be used to either reduce the duty on circuit breakers or increase the continuity of power supply or reliability of this service to the customer.

The speed of circuit breakers and relays in relation to power system stability may conveniently be analyzed under 3 headings as follows:

1. Conventional or slow-speed breakers and relays for fault isolation.
2. High-speed breakers and relays capable of isolating fault in time to improve stability limit.
3. High-speed breakers and relays with reclosure in time to improve stability limit.

Examination of the curves of figures 11 and 12 will show that conventional slow-speed circuit breakers and relays of the type commonly in use prior to 1929 were so slow from the stability point of view that the limits corresponded to sustained faults. In this connection it may be observed also that the power limit for the 3-phase fault is almost negligible with the conventional slow-speed breakers formerly in use. The benefits which arise from the use of high-speed circuit breakers and relays in maintaining stability depend upon isolating the fault in an interval of time which is short in respect to the period of system oscillation. The preceding discussion has been based on the isolation of the fault in a single step. For sequential operation the individual breaker times will be less than that shown but need not be reduced to half value. This is, of course, due to the fact that the stability conditions are generally much improved upon the operation of the first circuit breaker.

With the development of higher speed circuit breakers it is now possible to obtain speeds of operation of 8 cycles for the full range of transmission voltages. In addition for special cases still faster speeds of operation, such as 3-cycle breakers, have been developed to meet the particular situation.

With composite systems involving long transmission lines from a source of power with interconnecting lines between various parts of the receiver, system studies will frequently show the desirability of using high-speed circuit breakers and relays in order to increase the stability limits. In a number of such cases it will be important to extend the application of the high-speed breakers to interconnecting lines of the receiver system. Otherwise, the stability limits will be determined not by faults on the main transmission line but by faults on the receiving system even though it is operating at lower voltage with transformers between it and the transmission line.

This development in the speed of circuit breakers has brought about important changes in the relaying of transmission lines. With fast circuit breakers it is no longer feasible to contemplate relay operating times of $^1/_4$ second to 3 seconds or the use of time intervals as the basis of discrimination. This has led to the use of distance or current balance types of relays which are capable of simultaneous action for the middle section of a transmission line with high-speed sequential tripping for the end sections.

In cases where the transmission system will be operated relatively close to the stability limits there is considerable advantage in providing simultaneous breaker operation. In general, such relay operation can be obtained only through the use of fundamental frequency relays operating in conjunction with a signal transmitted by pilot wires or carrier current between the ends of the line section. This has brought about an important development in the application of high-speed relaying with superposed carrier frequency. Various proposals have been considered as to the type of carrier signal to be transmitted. The relay indication to be transmitted by carrier frequency was considered first as some electrical indication, such as direction of the flow of power, but more recently as the position of various fundamental frequency relay elements which indicates the existence of a fault on the system within predetermined zones. The carrier-current relay system also provides opportunity for including relay measures for the prevention of undesired breaker operations in the event that the system does pull out of step.

Reclosing Circuit Breakers

The use of reclosing circuit breakers provides a means for carrying one step further the advantages possible with high-speed breakers and relays for fault clearing. For lower voltage systems and feeder circuits the use of automatic reclosing breakers makes it possible to maintain the stability of a system with induction motor load. Disconnection of the source is required for the suppression of the arc in the fault but the total time required for disconnection and for reclosure should be made sufficiently short as to prevent pullout of induction motor load. Where synchronous machines may maintain the arc, it is

ecessary to isolate the affected line and to reconnect it n a period of time that is relatively short with respect o the period of system oscillation if stability is to be ttained. Hence, if automatic reclosing breakers are onsidered for maintaining the stability on a transmission ystem it becomes a practical necessity to use carrier urrent relaying. The existence of multiple or repetitive ightning discharges may constitute an important factor n limiting the application of reclosing breakers for maintaining stability.

Single-pole breakers have been proposed at frequent ntervals as a means for improving the stability of a ransmission system. This device has been advocated on he basis that the remaining phases may be used to transmit power and thus minimize the system disturbance during the transition from the condition before the fault to he condition after the fault when the faulty line is disconnected. Most line interruptions which do not permanently ground a transmission conductor are due to lashovers which must be isolated to put out the arc-to-ground. Thus it is usually permissible to reclose the aulty line and restore the system to its original condition without at any time reducing the power limits to as low a value as would be the case if all three conductors were disconnected. To minimize objection to residual earth urrent from the standpoint of inductive co-ordination, it has been proposed to use breakers which are operated as single-pole units for arc suppression and reclosure but which are gang-operated for sustained faults. The advantages of single-pole reclosing breakers are minimized by the trend in the direction of providing protection against the more severe types of faults. To date the single-pole breaker scheme has not been installed on any transmission system.

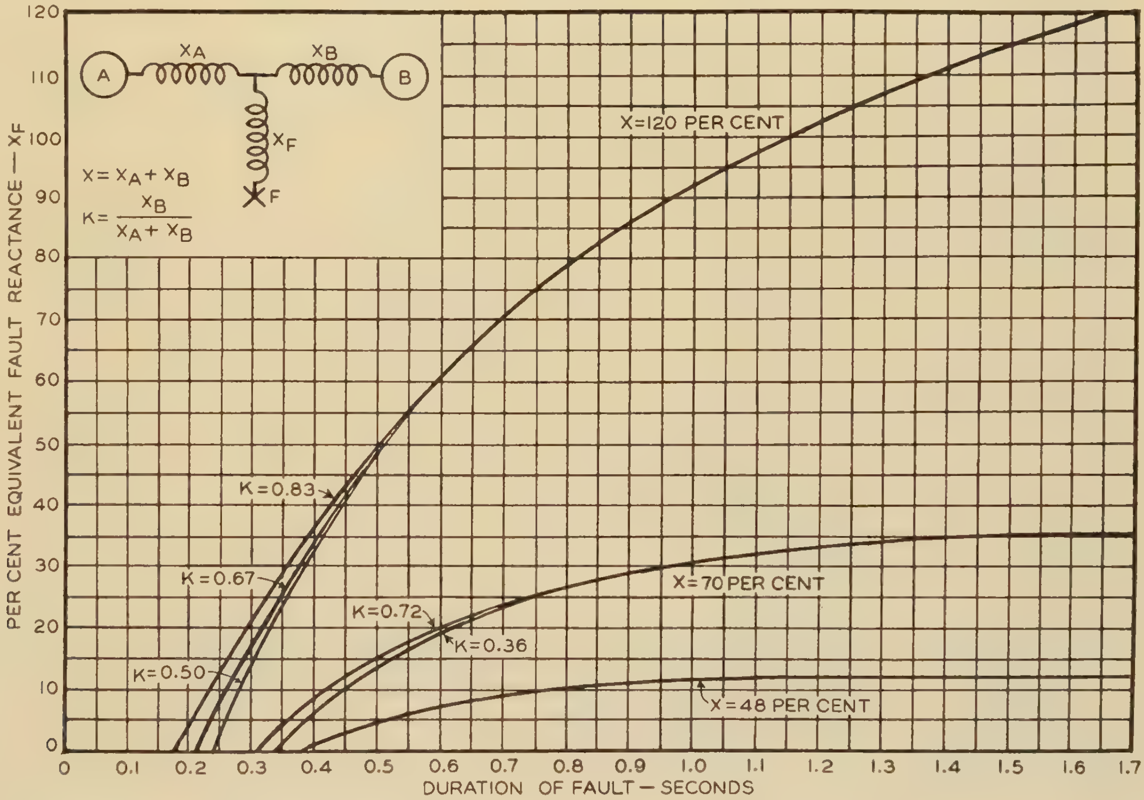


Fig. 12. Stability limits for metropolitan-type systems with steam-turbine generators; no voltage regulators

A—Steam turbine under consideration

B—System

Other Methods of Increasing the Practical Operating Power Limits

Flashover Prevention and Arc Suppression

Flashover prevention and arc suppression constitute a different type of measure for improving system operation. It is obvious, of course, that a system rarely subjected to faults may be operated relatively close to the stability limits. Consequently, under some conditions it is more advantageous to spend money for minimizing the likelihood of faults than in increasing the capacity of the system to withstand the system disturbances without loss of synchronism.

The principal cause of flashover on high-voltage lines is lightning. Much has been accomplished during the past 5 years to minimize flashovers resulting not only from induced strokes but particularly from direct strokes. Increased transmission line spacing and increased use of insulation in the form of insulator strings and wood have been generally adopted. On the higher voltage lines the use of ground wires is of great value when suitably located with respect to the conductors to be protected. Special efforts have been made to reduce the tower-footing resistance to a relatively low value in order to prevent a flashover of the insulator string as a result of the building up of high potential due to the flow of lightning current through the tower.

	Los Angeles Bureau of Power & Light	Metropolitan Water District of So. California	Southern California Edison Co.	Pacific Gas & Electric Co.		Puget Sound Power & Light Co.	
	Item I Boulder Dam-Los Angeles	Item I Boulder Dam Line	Item I Big Creek Line	Item I Tiger Creek-Newark	Item II Bucks Creek-Wilson	Item I Baker River Nos. 1 & 2	Item II Rock Islar No. 1
A. Transmission							
1. Voltage, kilovolts	287.5	230	220	220	220	110	110
2. Distance, miles	267	237	240	109	185	67	134
3. Frequency, cycles	60	60	50	60	60	60	60
4. Power, kilowatts sent out	240,000	330,000	400,000	150,000	120,000	40,000	25,000
B. Circuit arrangement							
1. Number of circuits	2	1	3	2	2	2	1
2. Intermediate switching stations	2	None	4	None	1	1	None
3. Load taken off at intermediate points, kilowatts	None	None	135,000	None	None	None	None
4. Synchronous condenser, kva at intermediate points	None	None	None	None	None	None	None
. Bussing arrangements							
a. Sending end	H. T	H. T	H. T	None	None	None	None
b. Receiving end	L. T	H. T	H. T	None	None	None	None
6. Grounding							
a. Sending end	Solid	Solid	Solid	Solid	Solid	Solid	Solid
b. Receiving end	Solid	Solid	Solid	Solid	Solid	Solid	Solid
C. Generator							
1. Kilovolt-amperes	Each 82,500	Each 82,500	15 units, total 397,000			39,000	66,668
2. Short circuit ratio (or synchronous reactance, per cent)	2.4	2.4	1.6				
3. Transient reactance X_d' per cent	17.5	17.5	22	27	27	23	30
4. Inertia constant H	9.5	4.7	3.74	4.1	4.1	4.05	4.45
5. Damper winding	Copper	Copper	None	None	None	Copper	Copper
D. Excitation system							
1. Exciter response, per unit (figure 10) self- or pilot exciter	0.5 Pilot	0.5 Pilot	1.0 Pilot	1.5	1.5	240 volts/sec.	200 volts/s
E. Breakers and relays							
1. Breaker speed, cycles	3	8	8-26	12	12	18	8
2. Relaying type	Carrier current and cross balanced between [illegible] circuits—3 cycles	Instantaneous overcurrent	Instantaneous overcurrent & simultaneous carrier current on some lines	Overload & directional residual	(Same as item I)	Balanced current	High speed distance
3. Total time, cycles*	6	8.5	8.5–31	13–14	13–14	27–54	9
F. Lightning protection							
1. Tower construction	Steel	Steel	Steel	Steel	Steel	Wood pole H frame	Steel over mountains, rest is woo pole H fran
2. Ground wires	2–50′ spacing on 1 circuit towers—40.5 on 2 circuit towers	None	2	None	None	None	None
3. Counterpoises	Continuous —2 wires per tower line, cross connect to adjacent towers.	None	None	None	None	None	None
4. Insulators	Susp: Single—24, 10″ x 5″ units Deadend: Double, 22 10½″ x 6″ units	Susp: 13–10″ diam., 5¾″ spacing Deadend: 15-same	Susp: 12–10″ units Deadend: 13-double, same	13 5½″ units Semi-fog section, 14 5½″ units Fog section, 20 5½″ units	14 5½″ units	Susp: 6–10″ units Deadend: 7-same	(Same as item I)
5. Lightning arresters	Yes	None	None	None	None	Yes	Yes

* Note—In certain cases of sequential tripping, time given applies to breaker only.

The use of the ground wire tends to reduce the zero-sequence impedence of the system and thus to increase the severity of the shock resulting from a single fault-to-ground or a double fault-to-ground. With the improvements in high-speed circuit breakers and relays these faults may be cleared promptly; consequently, the use of ground wires results in a gain from the stability point of view in reducing the number of flashovers which overbalances any disadvantage from the standpoint of the shock to the system in case fault occurs.

The fault suppression measures have as their object the interruption of the power-arc following a flashover without the necessity for isolating the affected circuit. The use of fused arcing rings or special tube type protectors in parallel with the insulators permits flashover to take place with the subsequent interruption of the power arc. Lightning arresters distributed along the line will accomplish this same general objective.

Arc-suppression devices of the Petersen type have received consideration for minimizing circuit outages in com-

ern ras r Co.	Platte Valley Public Power & Irrigation Dist.	Union Electric Light & Power Co.		The Milwaukee Electric Railway & Light Company		Super Power Co. Ill. Ill. North. Utilit. Co. & Public Service of Northern Ill.	Super Power Co. of Illinois & Public Service Co. of Northern Illinois		
I Dam e	Item I North Platte-Columbus	Item I Osage-Cahokia	Item II Osage-Page	Item I Lakeside-Granville	Item II Port Washington-Granville	Item I Powerton-Waukegan	Item II Powerton-Waukegan	Item III Powerton-State Line	
									A
2	115	132	132	132	132	132	132	132	1
2	218.5	177.9	135.5	25	23	218.6	243.4	202.4	2
0	60	60	60	60	60	60	60	60	3
00	25,000	90,000	45,000			55,000	55,000	60,000	4
									B
	1	2	1	1	1	1	1	53 mi: 2 149.4 mi: 1	1
e	2	2	None	1	None	2	4	4	2
e	12,000	20,000	None	None	None	30,000	50,000	35,000	3
e	8,000	50,000	None	None	None	None	20,000	15,000	4
									5
e	L. T.	None	None	L. T.	L. T.	None	None	None	a
e	H. T.	L. T.	L. T.	H. T.	H. T.	H. T.	H. T.	L. T.	b
									5
d	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	a
d	Solid	Solid	Solid	None	None	Solid	Solid	Solid	b
									C
00	2 units, each 14,500	4 units, each 23,888	2 units, each 23,888	375,000	94,000	61,765	61,765	116,666	1
6	115.5	1.15	1.15	0.87 & 1.24	0.92	120	120	107	2
3	32	30	30	15	15.5	23	23	20	3
8	2.05	3.56	3.56			5.75	5.75	5.5	4
per	Copper	None	None			None	None	None	5
									D
5	1.0	1.5	1.5	Hand	Hand	0.3	0.3	1.0	1
ot	Pilot	Pilot	Pilot	regulation	regulation	Self	Self	Pilot	2
									E
)	8	7	8	12	8	8-20	8-20	8-20	1
nduction pedance rection- tion	Distance	Distance	Distance	Induction type	Induction type	Distance	Distance	Distance	2
Min.)	9–10	8–10	9	93	39	10–56	10–74	10–74	
									F
el	Wood pole H frame	120 mi. steel with wood arms; 58 mi. steel	Wood pole H frame	Steel	Steel	166 mi.: steel 52 mi.: wood	Steel	Steel	1
ne	None	147 mi.—2; 31 mi.—1	2	1	1	185 mi: 2; 34 mi.: 1	187 mi.: 2; 57 mi.: 1	173 mi.: 2; 30 mi.: 1	2
ne	None	None	None	None	None	None	None	None	3
–10" 1: 10-	Susp: 7–10" × 5 3/4" units Deadend: 8-same	147 mi.: 11–5 3/4" units 31 mi: 10–4 3/4" units	11–5 3/4" units	Susp: 10–4 3/4" units Deadend: 12-same	(Same as item I)	103.5 mi.: 12–OB25620 72.9 mi.: 10–5 3/4" units 42.2 mi.: 8–JD2501	53 mi.: 12–OB25620 67.4 mi.: 13–OB25622 123 mi.: 8–JD2501	53 mi.: 12–OB25620 67.4 mi.: 13–OB25622 82 mi.: 8–JD2501	4
es	Yes	Yes	Yes	Yes	Yes	3 stations—yes 1 station—no	3 stations—yes 3 stations—no	4 stations—yes 2 stations—no	5

ction with multiple-circuit system of the type in common use and with recently proposed single-circuit transmission line system. In America, however, little use is ade of this type of arc-suppression device as dependence placed on circuit-breakers and relays for automatically olating a faulty section of line. This can be accomished under favorable conditions even on high voltage rcuits in about 12 cycles. This scheme has the merit of ppressing all types of faults that occur on systems rerdless of whether they are of the single line-to-ground or more severe types. In addition it permits grounding the system so that the tendency for a single-phase fault to develop into a multiphase fault is minimized.

High-Voltage Low-Frequency A-C and D-C Transmission

Low-frequency a-c systems have been proposed frequently for increasing the practical operating stability limits of long-distance transmission systems. More recently d-c transmission has been proposed as a means for

	Public Service Co. of Northern Illinois		Northern Indiana Public Service Co.			Public Service Company of Indiana		D Edi
	Item I Waukegan Northwest	Item II Waukegan Northwest	Item I Michigan City-State Line	Item II Michigan City-South Bend	Item III Mich. City-S. Bend Monticello	Item I Dresser-Lenore	Item II Columbia-Lenore	I Ma No
A. Transmission								
1. Voltage, kilovolts	132	132	132	132	132	132	132	
2. Distance, miles	36.88	36.88	50.6	40.5	101.0	74.8	91.68	
3. Frequency, cycles	60	60	60	60	60	60	60	
4. Power, kilowatts sent out	80,000	80,000	80,000	55,000	25,000	40,000	10,000	4
B. Circuit arrangement								
1. Number of circuits	1	1	1	1	1	2	1	
2. Intermediate switching stations	None	None	1	None	1	None	1	N
3. Load taken off at intermediate points, kilowatts	None	None	45,000	None	8,000	None	None	N
4. Synchronous condenser, kva at intermediate points	None	None	None	None	None	None	None	N
5. Bussing arrangements								
a. Sending end	H. T.	H. T.	H. T.	H. T.	H. T.	L. T.	L. T.	H
b. Receiving end	L. T.	L. T.	L. T.	H. T.	L. T.	L. T.	L. T.	H
6. Grounding								
a. Sending end	Solid	Solid	Solid	Solid	Solid	Solid	Solid	S
b. Receiving end	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Ung
C. Generator								
1. Kilovolt-amperes	2 units, total 129,525	121,000	70,600	70,600	70,600	3 units, each 25,000	2 units, each 78,610	6 uni 19
2. Short circuit ratio (or synchronous reactance, per cent)	1 unit, 152; 1 unit, 154	161	111	111	111	122		
3. Transient reactance X_d', per cent	1 unit, 16.3; 1 unit, 18.6	18.4	23.9	23.9	23.9	13		
4. Inertia constant H	1 unit, 4.95 1 unit, 4.14	4.64	4.09	4.09	4.09	3.74		
5. Damper winding	None	None	None	None	None	None	None	N
D. Excitation system								
1. Exciter response, per unit (figure 10) self- or pilot exciter	0.5 Self	1.5 Pilot	0.384 Self	0.384 Self	0.384 Self	Unknown Self	Self	Hand tion
E. Breakers and relays								
1. Breaker speed, cycles	8	8	12–25	8–12	8–12	6–7	7–13	
2. Relaying type	Distance & overcurrent	Distance & overcurrent	Distance	Distance & overcurrent	Distance & overcurrent	Overcurrent	Overcurrent	Diffe
3. Total time, cycles*	10–60	10–60	13–67	10–14	12–45	Line: 9–67; G'nd: 9–25	Line: 39–67; G'nd: 12–53	
F. Lightning protection								
1. Tower construction	Steel	Steel	Steel	Steel	Steel	Steel	Steel	S
2. Ground wires	2	2	1	1	1	1	1	
3. Counterpoises	None	None	None	None	None	None	None	
4. Insulators	8–JD2501	8–JD2501	8–6½″ units	8–6½″ units	8–6½″ units	Susp: 9–10″ x 4¾″ units Deadend: 11-same	(Same as item I)	Su Dead
5. Lightning arresters	None	None	Yes	Yes	Yes	Yes	Yes	Y

* Note: In certain cases of sequential tripping, time given applies to first breaker only.

avoiding the stability limits since such a system inherently provides a nonsynchronous tie. In America, 60-cycle alternating current is very generally established for utilization. Consequently, the proposals to use low-frequency a-c and high-voltage d-c transmission schemes have included conversion means at the receiving end. In general, the use of the low-frequency a-c system involves no new problem in apparatus or application so that its use is not hindered on this account, though static apparatus may find application in the field of frequency conversion. In the case of d-c transmission, however, the conversion from a-c generation to the d-c high voltage required for the transmission line involves rectifiers for which there is no comparable operating experience; in the case of the invert-

m I inaw- int	Consumers Power Company Item II Muskegon- Grand Rapids	Item III Croton- Grand Rapids	Item IV Jackson- Superior	Item V Flint- Delhi	Item VI Kalamazoo- Battle Creek	Item VII Delhi- Jackson	Item VIII Toronto- Akron	Tennessee Valley Authority Item I Wilson- Norris	
									A
40	140	140	132	140	140	140	132	154	1
.3	36.2	47.1	28.8	19.4	14.3	26.5	64.0	233.4	2
0	60	60	60	60	60	60	60	60	3
,000	50,000	67,800	77,500	25,000	25,000	65,000	50,000	50,000	4
									B
2	1	1	1	1	1	1	1	1	1
one	None	None	None	None	None	None	None	None	2
one	None	None	None	None	None	None	None	None	3
one	None	None	None	None	None	None	None	None	4
									5
T	H. T.	H. T.	Through transformer	H. T.	H. T.	H. T.	H. T.	H. T.	a
T	H. T	H. T	Through transformer	H. T	H. T	H. T	L. T	L. T.	b
									6
ed al	Isolated neutral	Isolated neutral	Isolated neutral	Isolated neutral	Isolated neutral	Isolated neutral	Solid	2 reactors (each 35 ohms)	a
ed al	Isolated neutral	Isolated neutral	Solid	Isolated neutral	Isolated neutral	Isolated neutral	Solid	Solid	b
									C
,000	50,000	50,000			50,000		140,000	2 units, each 56,00 (at Norris)	1
1.0	1.0	1.0			1.0		1.0	1.045	2
-12	10–12	10–20					10–12	40.7	3
									4
								Copper	5
									D
.0 lot	Pilot	Pilot			Pilot		Pilot	1.0 Pilot	1
									E
20	8–20	8	8–20	8–20	8–20	8–20	8–20	8	1
lance	Step distance	Step distance	Impedance	Impedance	Impedance	Impedance	High-speed step distance	Simultaneous with carrier, or sequential with distance	2
-32	10–22	10	20–32	20–32	20–32	20–32	10–22		3
									F
eel	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel except Tenn. R. to Monteagle (wood)	1
l	2	1	1	1	1	1	1	2	2
one	None	None	None	None	None	None	None	None	3
-4³/₄″ units units d: 11- its	Susp: 10–5³/₄″ units Deadend: 11-same	(Same as item II)	Susp: 10–5″ units Deadend: 12-same	Susp: 10–5³/₄″ units Deadend: 11-same	Susp: 9–4³/₄″ units Deadend: 12-same	Susp: 10–4³/₄″ units Deadend: 12-same	Susp: 10–5³/₄″ units Deadend: 11-same	17.5 miles; Susp: 19–5¹/₈″ units Deadend: 21 same. 96 miles; Susp: 9–6¹/₂″ units Deadend: 11 same. 120 miles; Susp: 16–6¹/₂″ units or 19–5¹/₈″ units Deadends: 21–5¹/₈″ units	4
es	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	5

rs at the receiving end still less work has been done. Consequently, d-c transmission has received very little practical onsideration, although a 5,000-kw experimental d-c ransmission system, which will transmit power 17 miles t 30,000 volts, is being built to obtain operating experience.

At the present time the limitations in 60-cycle systems, from the standpoint of system stability, are not of sufficient importance as to justify the adoption of either low-frequency a-c or high-voltage d-c transmission. The possible field for d-c transmission will depend largely on the usefulness of its operating characteristics aside from stabilty and on the future development of conversion apparatus. In this connection it should also be recognized that

	Pennsylvania Water and Power Co. Item I Safe Harbor-Washington	Pennsylvania Water and Power Co. Item II Safe Harbor-Perryville	Philadelphia Electric Co. Item I Conowingo-Plymouth Mtg.	Philadelphia Electric Co. Item II Plymouth Mtg.-Westmoreland	Pennsylvania Power & Light Co. Item I Plymouth-Siegfried	Pennsylvani[a] — Public Service Electric & Gas Company of New Jersey Item I Roseland-Plymouth Mtg.	Pennsylvani[a] — Public Service Electric & Gas Company of New Jersey Item II Roseland-Siegfried
A. Transmission							
1. Voltage, kilovolts	230	132	220	66	220	220	220
2. Distance, miles	92	30	57.6	10	38.8	75.8	83.7
3. Frequency, cycles	60	25—1 phase	60	60	60	60	60
4. Power, kilowatts sent out	168,000	49,400	252,000	212,000	185,000	200,000	200,000
Circuit arrangement							
1. Number of circuits	1	4	2	3	1	1	1
2. Intermediate switching stations	None	None	None	None	None	None	None
3. Load taken off at intermediate points, kilowatts	None	None	None	None	None	None	None
4. Synchronous condenser, kva at intermediate points	None	None	None	None	None	None	None
5. Bussing arrangements							
a. Sending end	None	None	None	None	None	None	None
b. Receiving end	None	None	None	None	None	None	None
6. Grounding							
a. Sending end	Solid	Midpoint of transfs. grounded through 330-ohm resistance	Solid	Solid	Solid	Solid	Solid
b. Receiving end	Solid		Solid	Solid		Interconnected with P. E. Co.	Interconnected P.P. & L. Co.
C. Generator							
1. Kilovolt-amperes	5 units, total 155,500	35,000—Gen. 31,250—Freq. chgr.	7 units, total 280,000				
2. Short circuit ratio (or synchronous reactance, per cent)							
3. Transient reactance X_d', per cent	26.7–29.0	27.5	26–28				
4. Inertia constant H	3.31	4.3	2.84–3.69				
5. Damper winding	Copper	Copper	None				
D. Excitation system							
1. Exciter response, per unit (figure 10) self- or pilot exciter	225 volts/sec	200 volts/sec	3.2–3.5				
E. Breakers and relays							
1. Breaker speed, cycles	8	3.5	8–12	8	10	3.5	3.5
2. Relaying type	Distance	Voltage balance	Phase: Induction impedance g'nd: hi-speed diff. & hi-speed directional overcurrent	Phase: Differential g'nd: hi-speed induct type directional overcurrent	Phase: Distance g'nd: Instantaneous overcurrent	Distance	Sequential w distance
3. Total time, cycles*	9–10	8.5	Phase: 9–18 G'nd: 9–18	Phase: 20–60–150 Gn'd: 9–18–60	11–75	10	10
F. Lightning protection							
1. Tower construction	Steel	Steel	Steel	Steel	Steel	Steel	Steel
2. Ground wires	2	2	2	2	2	2	2
3. Counterpoises	Crowfoot system	Crowfoot system	None	Continuous type, 3.7 mile section	None	None except gndg. cable at high res. tower footings	(Same as ite
4. Insulators	20–5 1/4" units	12–5 1/4" units	Susp: 16–5 3/4" units Deadend: 18-same	Susp: 8–5 3/4" units Deadend: 9-same	Susp: 16–5 3/4" units Deadend: 18-same	Susp: 18–5 3/4" units Deadend: 20-same	(Same as it
5. Lightning arresters	Yes	None	Yes	Yes	None	None	None

* Note: In certain cases of sequential tripping, time given applies to first breaker only.

there is a possibility of an improvement in a-c transmission at normal frequencies.

Recent Practices Regarding Stability Features

In order to summarize the present status of the stability problem from the practical standpoint of its effect on power system design, table III has been prepared. This table gives the principal installations made during the past 10 years and lists the data on the various stability measures employed. While the list of installations is obviously incomplete, nevertheless, it is believed that the list is representative of the practice in regard to stability.

Future Developments

In concluding this "First Report on Power System Stability," it is natural to turn from consideration of the

g Stability Studies

Interconnection									
ia ght	Philadelphia Electric Co.		Niagara-Hudson Power Corporation			New England Power Service Company	Hydro-Electric Power Comm. of Ontario	The Shawinigan Water & Power Co.	
l- d	Item III New Hope-Plymouth Mtg.	Item IV Towamencin-Plymouth Mtg.	Item I Pleasant Valley-Dunwoodie	Item II Inghams-Rotterdam	Item III Buffalo-Lockport	Item I Comerford-Tewksbury	Item I Ottawa River-Toronto	Item I Ile Maligne-Quebec	
									A
	220	220	132	110	110	230	220	187	1
	29.6	9.9	62.5	47	21	126	200	136	2
	60	60	60	60	60	60	25	60	3
0	40,000	65,000	160,000	130,000	120,000	156,000	200,000	160,000	4
									B
	1	1	2	2	2	2	3	2	1
	None	None	1	None	None	1	None	None	2
	None	None	20,000	None	None	None	None	None	3
	None	None	None	None	None	None	None	30,000	4
									5
	None	None	H. T	H. T	H. T	H. T	H. T	L. T.	a
	None	None	H. T	H. T	L. T	H. T	H. T	H. T.	b
									6
			Solid	Solid	Solid	30-ohm resistor	Solid	Solid	a
	Solid	Solid	Solid	Solid	Solid	30-ohm reactor	Solid	Solid	b
									C
			On P. V. 1,388,000 On Dun. 1,900,000	On Ingh. 979,000 On Rott. 2,300,000	On Bflo. 225,000 On Lock. 3,060,000	4 units, each 39,000	Each 23,500 to 28,500	11 units, each 30,000	1
						.81	1.25	90	2
			15.4 / 9.8	16.1 / 12.2	12.7 / 45.8	31	28	41	3
			2.85 / 6.58	2.9 / 6.2	4.5 / 5.05	2.73	3.1	3.03	4
						Inner; copper; outer, Everdur	None	None	5
									D
						1.6 Pilot	1.8 Pilot		1
									E
	8	8–12	8	8	8	8	3.5–4 (Some—8–10)	10–12	1
ance a- er-	Phase: hi-speed imp. directional relay g'nd: directional overcurrent	(Same as item III)	Simultaneous with carrier current	Overcurrent with instantaneous & differential	Differential current & distance	Sequential with balanced current & distance	Sequential with impedance distance	Parallel line protection with a directional impedance standby	2
	Phase: 9–60 Gnd: 9–18 or 50–60	Phase: 9–75 G'nd: 9–35 or 70–90	12	10	12	9–11	5–5$^1/_2$ (Some—20)	12 up	3
									F
	Steel	Steel	Steel	Steel	Steel	Steel	Steel	Steel	1
	2	2	2	2	2	2	2	2	2
	None	None	None	None	None	None	None	Part continuous type & part 250′ on each side of tower	3
16 8-	Susp: 16–5$^3/_4$″ units Deadend: 18-same	(Same as item III)	Susp: 12 units Deadend: 13 units	Susp: 8 units Deadend: 9 units	Susp: 7 units Deadend: 9 units	Susp: 15–5$^3/_4$″ units Deadend: 17-same	Susp: 18–5″ units Deadend: 18-same	Susp: 10 units Deadend: 12 units	4
	Yes	Yes	Yes	Yes	Yes	Yes	Receiving end	No	5

ast practices and the present status and to contemplate e future. Probably the best forecast of the future can e made from an examination of the problems which are ceiving active consideration at the present time. These oblems include the development of faster breakers and lays, particularly of relays to meet the wide range of stem conditions to be encountered. Flashover-preven-on and arc-suppression measures are receiving a great eal of attention, particularly from the standpoint of the application of ground wires and lower tower-footing resistance on high-voltage lines, and flashover protector tubes for intermediate-voltage lines. Further study is being given to the reactances of synchronous machines, particularly as to the proper equivalent value to be used in stability studies. Reclosing breakers are receiving favorable consideration but much remains to be done to determine the extent of their proper field of application. The interconnection of individual power systems, each

with automatic frequency control for time-keeping purposes, has introduced problems which are receiving active consideration. Stability limits of particular systems are being examined from the standpoint of providing better instruction for the guidance of system operators during unusual or emergency circuit conditions.

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This is arranged in 2 parts. Part I is intended to give a substantially complete list of references to stability papers available in English, and part II gives a highly selected list of references to papers dealing with the solution of network problems which are inevitable in stability calculations. Foreign references have not been included because of their unavailability to the AIEE membership generally and also because of lack of space.

The arrangement of the bibliography contains some features requiring additional comment. The references are arranged in chronological order by years. However, within each year the papers are arranged alphabetically according to the authors' names. The arrangement has been selected for facilitating the search for a particular article, whether by author's name, title, or time of publication. In addition the character of papers is indicated from the standpoint of their present interest by means of the following symbols:

H—Historical interest
A—Analysis including methods of calculation
M—Discussion of measures for improving stability
T—Stability tests in the laboratory or in the field
O—Operating experience including means employed on specific projects
P—Physical explanation of stability phenomena
R—General review of stability problem

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Part II—Selected References on Network Solutions

This section is intended to include a highly selected list of references to methods of network solution and unbalanced fault calculation. While this material is in itself not strictly a part of the stability literature, the methods described are invaluable in actual stability calculation.

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News

Of Institute and Related Activities

A Feature of the AIEE 1937 Summer Convention

Opportunity to inspect the new Port Washington power plant of The Milwaukee Electric Railway and Light Company will be among the high spots of the AIEE summer convention, to be held in Milwaukee, Wis., June 21–25, 1937. Convention headquarters will be in the Schroeder Hotel.

Since placed in regular service December 1, 1935, this modern steam-electric generating station has achieved new world records for economy in operation. Latest available figures, for the first 10 months of operation, show an average coal consumption of 11,094 Btu per kilowatt-hour of station output. International recognition was given this plant recently when it was visited by 73 delegates, representing 15 foreign nations, to the Third World Power Conference (held in Washington, D. C., September 7–12, 1936).

The plant is designed on the unit plan, with a single boiler for each turbo-generator; also one set of transformers, one 132-kv transmission line and one set of auxiliaries for each unit. The present installation of 80,000 kw capacity is the first of a probable ultimate capacity of 400,000 kw in 5 units. Throttle pressure is 1,230 pounds per square inch, and steam temperature at both throttle and reheat point 825 degrees Fahrenheit. Generator voltage is 22 kv.

The convention transportation committee is making plans for transporting AIEE delegates to the plant, which is located at Port Washington on the shore of Lake Michigan about 28 miles north of Milwaukee.

The personnel of the 1937 summer convention committee is as follows: Otto H. Falk, *honorary chairman;* K. L. Hansen, *chairman;* L. H. Hill, *vice-chairman;* C. H. Krueger, *secretary;* W. E. Crawford, *treasurer;* R. R. Benedict, A. G. Dewars, C. F. Harding, H. S. Osborne, G. G. Post, J. A. Potts, D. L. Smith, and W. H. Timbie. Subcommittee chairmen: J. F. H. Douglas, technical program; E. W. Seeger, finance; L. W. Copeland, entertainment; C. D. Brown, transportation; W. O. Helwig, registration and housing; W. E. Gundlach, publicity; G. F. Crowell, sports; S. H. Mortensen, inspection trips, and Mrs. A. C. Flory, ladies.

Port Washington plant of Milwaukee (Wis.) Electric Railway and Light Company

Washington Award for 1937 Announced

Doctor Frederick Gardener Cottrell, Washington, D. C., who perfected the process by which the cost of helium gas was reduced from $1,700 to 10 cents per cubic foot, has been chosen to receive the Washington Award for 1937 "for his social vision in dedicating to the perpetuation of research the rewards of his achievements in science and engineering." A bronze plaque set in marble, the tangible symbol of the award, will be presented to Doctor Cottrell on February 23. Doctor Cottrell is president of Research Associates, Inc., and is widely known as a chemist and metallurgist, a former director of the United States Bureau of Mines, and director of the fixed nitrogen laboratory of the United States Department of Agriculture. Besides his achievements in the cheap production of helium, he is famous for his work in nitrogen fixation, for his processes of cleansing gases of dust and dirt by electrical precipitation, and for research in petroleum technology.

Doctor Cottrell is the fourteenth noted American engineer to receive this coveted award since it was founded in 1916 by John Watson Alvord of Chicago. The award is administered by the Western Society of Engineers in co-operation with the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the AIEE. The award is made annually—providing the members of the commission agree on a deserving candidate—as an honor conferred on a brother engineer by his fellows for accomplishments which pre-eminently promote the happiness, comfort, and well-being of humanity. There have been several years when no award was made.

Winter Convention to Be Reported in March Issue

As this issue goes to press, the Institute's 1937 winter convention is under way at New York. Marking the resumption of a 5-day winter convention schedule, the meeting has all appearances of being a highly successful affair. First day's registration was 470, compared with 602 in 1936, 633 in 1935, and 433 in 1934. On the second day 357 registered, compared with 444 in 1936, 301 in 1935, and 433 in 1934.

A complete report of the convention and its various features is scheduled for inclusion in the March issue.

Columbia University Offers E.E. Scholarship

The governing bodies of Columbia University have placed at the disposal of the AIEE each year a scholarship in electrical engineering in the school of engineering of Columbia University for each class. The scholarship pays the annual tuition fees of $380. Reappointment of the student to the scholarship for the completion of his course is conditioned upon the maintenance of a good standing in his work.

To be eligible for the scholarship, the candidate recommended will have to meet the regular admission requirements in,

regard to which full information will be sent without charge upon application to the secretary of the University or to the national secretary of the Institute.

In a letter addressed to the national secretary of the Institute, an applicant for this scholarship should set forth his qualifications (age, place of birth, education, reference to any other activities, such as athletics or working way through college, references, and photograph). A committee composed of W. I. Slichter, *chairman*, Francis Blossom, and H. C. Carpenter will consider the applications and will notify the authorities of Columbia University of their selection of a candidate. The last day for filing of applications for the year 1937–38 will be June 1, 1937.

The course at the Columbia school of engineering is a graduate course which may be either elective leading to the degree of master of science or prescribed leading to the degree of electrical engineer. For the former, requirement for admission is the completion of 4-year course in electrical engineering as evidenced by a bachelor's degree from an approved institution. For the professional degree, the requirements are more specific as to course content and include a considerable proficiency in mathematics, physics, and chemistry, and some knowledge of the humanities, as well as the usual undergraduate technical courses. The candidate is admitted on the basis of his previous collegiate record without undergoing special examinations. Other qualifications being equal, members of the student Branches of the AIEE will be given preference.

The purpose of this advanced course is to produce a high type of engineer, trained in the humanities as well as in the fundamentals of his profession. It is hoped that Enrolled Students and others qualified will show a keen interest in this scholarship.

Who's Who in Engineering

That all qualified engineers will be included in the fourth (1937) edition of "Who's Who in Engineering," is the expressed hope of those participating in the preparation of that volume. First issued in 1922–23, reissued in 1925 and 1931, "Who's Who in Engineering" has made a place for itself as a reference and record volume. Its principal failing has been that many qualified engineers have not been included, a deficiency that apparently came about through the failure of individuals to return questionnaires with the data required for the preparation of entries. Through the active co-operation of American Engineering Council, it is now hoped that this earlier deficiency can be overcome, although the final answer still rests with individuals.

Questionnaires were mailed some weeks ago "to every engineer for whom a permanent address [was] available, so that none may be missed." Chairman Potter of AEC's committee urges Institute members to co-operate by promptly filling and returning these questionnaires. It is pointed out that "space in the volume cannot be purchased," and that there is no obligation.

Electronic Tube Nomenclature Being Studied

Generic Term	Output Energy	Character of Space	Control Means	Type Cathode	Names	Definition
*Electronic Tubes (or Tanks)	Electrical	High-Vacuum	None	Thermionic	Kenotron	A high-vacuum thermionic tube in which no means is provided for controlling the unidirectional current flow
				Photoelectric	Phototube	A vacuum tube in which electron emission is produced directly by radiation falling upon an electrode. A high-vacuum phototube is one that is evacuated to such a degree that its electrical characteristics are essentially unaffected by gaseous ionization
			Electrostatic	Thermionic	Pliotron	A high-vacuum thermionic tube in which one or more electrodes are employed to control the unidirectional current flow
			Electromagnetic	Thermionic	Magnetron	A high-vacuum thermionic tube in which a magnetic field is employed to control the unidirectional current flow
		Gas-Filled	None	Thermionic	Phanotron	A hot-cathode gas-discharge tube in which no means is provided for controlling the unidirectional current flow
				Cold	Glow Tube	A cold-cathode gas-discharge tube in which no means is provided for controlling the unidirectional current flow
				Pool	Pool Tube (or Tank)	A gas-discharge tube (or tank) with a pool-type cathode (liquid or solid) in which no means is provided for controlling the unidirectional current flow
				Photoelectric	Phototube	See phototube definition under "high-vacuum tubes." A gas phototube is one into which a quantity of gas has been introduced, usually for the purpose of increasing its sensitivity
			Electrostatic Electrode	Thermionic	Thyratron	A hot-cathode gas-discharge tube in which one or more electrodes are employed to control electrostatically the starting of the unidirectional current flow
				Cold	Grid-Glow Tube	A cold-cathode gas-discharge tube in which one or more electrodes are employed to control electrostatically the starting of the unidirectional current flow
				Pool	Grid-Pool Tube (or Tank)	A gas-discharge tube (or tank) with a pool-type cathode (liquid or solid) in which one or more electrodes are provided for controlling electrostatically the starting of the unidirectional current flow
			Ignition Electrode	Pool	Ignitron	A gas-discharge tube (or tank) with a pool-type cathode (liquid or solid) in which an ignition electrode is employed to control the starting of the unidirectional current flow in each operative cycle
			Electromagnetic			(Not used at present)
	Light					
	Ultraviolet					
	X-Ray					
	Cathode-Ray					

* "Electronic Tube" is a generic term, applied to various designs of tubes (or tanks) consisting of 2 or more elements in a container, usually of glass, and having a high vacuum or filled with gas at reduced pressure.

An important preliminary step toward alleviation of the chaotic situation that has prevailed in connection with the multifarious names of electronic tubes has been achieved, according to recent advices from the American Standards Association, of which the Institute is an active member-body. As a tentative basis for the simplification of tube nomenclature, both the General Electric and the Westinghouse Electric & Manufacturing companies have agreed to abandon any trademark rights either company had in the several names indicated in the accompanying tabulation, "in the hope that this agreement will pave the way for the adoption of these names as American standards." It is recognized that this is but an initial step, and that its principal significance is in connection with the names of tubes now commonly used for industrial purposes. As a forward step, however, this list of names is hailed with satisfaction in many quarters, and, until something better becomes available, has been adopted for use in ELECTRICAL ENGINEERING. Comments are invited.

Committee on Broadening of Institute Activities

To meet the insistent and repeated demand for a broadening of the Institute's activities to cover discussions of social and economic subjects having engineering aspects, the AIEE executive committee, at its meeting of December 10, 1936, authorized the appointment of a special committee on broadening of Institute activities. The committee appointed consists of the following:

H. S. Osborne, *chairman* (chairman, technical program committee)

T. F. Barton (chairman, committee on legislation affecting the engineering profession)

H. V. Carpenter (chairman, committee on code of principles of professional conduct)

L. W. W. Morrow (chairman, committee on coordination of Institute activities)

R. W. Sorensen (chairman, committee on economic status of the engineer)

I. M. Stein (chairman, publication committee)

W. H. Timbie (chairman, Sections committee)

J. B. Whitehead (chairman, committee on Institute policy)

Circumstances leading up to this action are outlined briefly in the following extract from the minutes of the executive committee:

"Further consideration was given to the subject of broadening Institute activities to cover discussions of social and economic subjects that have engineering aspects. At its October meeting, the board of directors passed a motion concurring in the suggestion that such topics are of general interest to electrical engineers, calling attention to 'the fact that the Institute has always offered facilities and organization for discussion of such questions,' and suggesting that papers on these subjects be submitted to the proper committees of the Institue for consideration for national presentation and publication.

"President MacCutcheon reported the impressions which he received when visiting Sections in the West and Middle West, and analyzed the attitude of the Institute membership as follows: Approximately 80 per cent of Institute members are in favor of a judicious broadening of Institute activities, but 60 per cent are strongly opposed to undertaking anything that would not be in the interest of the Institute, and about 20 per cent of them are inclined to go so far as to be in danger of damaging the profession and the Institute. He met with the executive committee of the Chicago Section and explained to them the board's attitude toward the suggestions of the group of Chicago members concerning the broadening of Institute activities. So far as Institute publications are concerned, it appeared that unquestionably 90 per cent of the members with whom he came in contact thoroughly agreed that they do not want to see any of the necessary technical material omitted, but they also desire something more; and that, Mr. MacCutcheon pointed out, will be taken care of by the appropriation in the budget for 100 additional pages in Electrical Engineering. He then referred to his efforts to secure papers on subjects of general interest from certain prominent men, and suggested the desirability of each member of the board making a similar effort, so that in 2 or 3 months such papers will be coming in.

"Then followed a discussion on the best procedure for handling the papers on social and economic subjects which may be submitted, or for procuring such papers. It was pointed out that in the Institute organization there are the technical committees to make sure that papers on technical subjects are forthcoming, but that there is no one who has particular jurisdiction over the papers on economics, administration, etc., which the membership seems to want. The desirability of setting up a particular committee for this purpose was discussed. The

Future AIEE Meetings

North Eastern District Meeting
Buffalo, N. Y., May 5–7, 1937

Summer Convention
Milwaukee, Wis., June 21–25, 1937

Pacific Coast Convention
Spokane, Wash., Date to be determined

Middle Eastern District Meeting
Akron, Ohio, Fall 1937

Westinghouse Commemoration at ASME Convention

The ninetieth anniversary of the birthday of George Westinghouse was commemorated December 1, 1936, during the 57th annual meeting of The American Society of Mechanical Engineers, by a special 2-session program which consisted of an afternoon session at which former friends and associates of Mr. Westinghouse brought personal testimony of his engineering achievements, and an evening session at which formal addresses were delivered. The group on the platform during the afternoon session is shown above; they are, standing, left to right: J. F. Miller, vice-chairman of the Westinghouse Air Brake Company, Pittsburgh, Pa.; N. W. Storer (A'95, F'13, member for life) retired consulting railway engineer of Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.; Thomas Campbell, veteran employee of the Westinghouse Air Brake Company; Francis Hodgkinson (A'02) consulting mechanical engineer and former turbine expert for the Westinghouse company, New York, N. Y.; A. W. Berresford (A'94, F'14, member for life, past-president) New York, N. Y.; C. R. Beardsley (A'08, F'30) superintendent of distribution of the Brooklyn (N. Y.) Edison Company; Roy V. Wright, editor of *Railway Age*, New York, N. Y.; and Charles F. Scott (A'92, F'25, HM'29, member for life, past-president) professor of electrical engineering emeritus of Yale University, New Haven, Conn.; seated, left to right: L. B. Stillwell (A'92, F'12, member for life, past-president) consulting engineer, Princeton, N. J.; W. W. Nichols, assistant to the chairman, Allis-Chalmers Manufacturing Company, New York, N. Y.; Frank W. Smith (A'05, M'12) president of the Consolidated Edison Company, New York, N. Y.; E. R. Hill (A'99, F'12, member for life) consulting engineer, Gibbs and Hill, New York, N. Y.; J. V. B. Duer (A'15, F'29) chief electrical engineer of the Pennsylvania Railroad Company, Philadelphia; and Samuel Vauclain, chairman of the board of the Baldwin Locomotive Works, Philadelphia. W. L. Batt and Ralph Budd also took part in the ceremonies.

Membership—

Mr. Institute Member:

Without your assistance your membership committee is definitely handicapped. Examine the roster of electrically interested individuals in your acquaintance and forward the names of men you would choose as Institute members, who are not now members, to the chairman of your Section membership committee. Personally obligate yourself to secure one new member for the Institute—YOUR INSTITUTE—your professional organization.

James M. Todd

Vice-Chairman, District No. 4
National Membership Committee

suggestion was made that the matter should be handled in a positive, rather than a negative, manner, by recognizing the demand on the part of the membership for the type of papers under discussion and taking the initiative in procuring such papers from the proper sources, so that dependence need not be placed entirely upon papers that originate spontaneously. The thought was expressed that diplomatic situations may arise unless there is some centralized specifying authority to investigate the possibilities before seeking a paper, and that a man who is approached to write a paper should be given the specifications for such paper.

"VOTED that a special committee on broadening of Institute activities be appointed, consisting of the chairman of the technical program committee as chairman, and the chairmen of the committees on code of principles of professional conduct, co-ordination of Institute activities, economic status of the engineer, Institute policy, legislation affecting the engineering profession, publication, and Sections."

Johns Hopkins Engineers to Mark 25th Anniversary. The school of engineering of The Johns Hopkins University, Baltimore, Md., will celebrate during the latter part of February 1937, the 25th anniversary of its founding. Plans include an "engineering show" that will involve displays of engineering equipment and principles, and from various sources exhibits are being gathered. At the "commemoration day" exercises to be held February 22, Dr. Karl Taylor Compton (F'31) president of the Massachusetts Institute of Technology is scheduled to deliver the principal address. During the exercises, honorary degrees will be conferred upon a small group of prominent engineers.

Arc-Welding Foundation Established. In order to stimulate scientific development, the Lincoln Electric Company has completed plans for establishing a fund and foundation to encourage study and research for the benefit of the industry. The fund has been named "The James F. Lincoln Arc Welding Foundation" in honor of the president of the company. Principal direction of the work of the foundation will be given by Doctor E. E. Dreese (M'25) chairman of the electrical engineering department of Ohio State University. Commenting on the action, Mr. Lincoln (A'08, M'20) stated

". . . . The sole purpose of this new foundation is to challenge the attention of manufacturers whose products benefit society; and to stimulate the ingenuity of every engineer and skilled worker interested in extending the frontiers of knowledge and achievement."

AIEE Members Among "12 Greatest Inventors"

Three deceased members of the AIEE were named among those chosen recently as America's "12 greatest inventors for the past century." The list of names was presented dramatically during a dinner held in Washington, D. C., to celebrate the 100th anniversary of the institution of the United States Patent Office. Those honored and their principal achievements were:

ALEXANDER GRAHAM BELL (A'84, M'84, deceased August 2, 1922) the telephone

THOMAS ALVA EDISON (A'84, M'84, HM'29, deceased October 18, 1931) the electric light and the phonograph

ROBERT FULTON, the first commercial steamboat

CHARLES GOODYEAR, the vulcanization process for rubber

CHARLES MARTIN HALL, aluminum manufacture

ELIAS HOWE, the first practical sewing machine

CYRUS HALL MCCORMICK, the first practical reaper

OTTMAR MERGENTHALER, the linotype

SAMUEL F. B. MORSE, the electric telegraph

GEORGE WESTINGHOUSE (A'02, deceased March 12, 1914) the air brake

ELI WHITNEY, the cotton gin

WILBUR WRIGHT, the airplane

American Engineering Council

Seventeenth Annual Meeting Held in Washington, D. C.

THE AIEE was represented at the seventeenth annual assembly of American Engineering Council in Washington, D. C., January 14 to 16, 1937, by its 5 delegates, President A. M. MacCutcheon, William McClellan, C. O. Bickelhaupt, C. E. Stephens, and National Secretary H. H. Henline. Many other Institute members were present at the several sessions either as members of committees, representatives of local clubs, or speakers, among which were included F. J. Chesterman, general chairman of the public affairs committee of AEC: Thomas R. Tate, chief of the power resources division of the Federal Power Commission and secretary of the AIEE Washington Section; and Harry W. Osgood, chairman of the Washington Section and member of the engineers dinner committee. Representatives of the 48 national, state, and local societies which comprise the Council were present. A report of the AEC meeting and the seventh conference of engineering society secretaries, as furnished by Frederick M. Feiker, executive secretary follows:

A session on programs of united action for member societies opened the conference of secretaries of engineering societies on the morning of January 14, O. L. Angevine, secretary of the Rochester (N. Y.) Engineers' Club presiding as chairman of the conference. Among the many discussions were those by A. A. Potter, president AEC, who spoke on intersociety co-operation, Watson Davis, of Science Service, whose subject was publicity, and F. J. Chesterman, who talked about public affairs. The conference continued throughout the afternoon with discussions on the co-ordination of programs and meeting dates, the Third World Power Conference, and various programs local societies had found to be successful.

That afternoon was also the occasion for meeting in informal round-table discussion of the AEC divisional committees. With F. M. Feiker, executive secretary, AEC, presiding, A. A. Potter, president, AEC, opened the discussion on operating commit-

es. The session was devoted to a prelimi-ry discussion of reports of AEC commit-es that were presented on January 15. cretary and Mrs. Feiker entertained the legates at a reception and tea at their me at the close of the session.

At a symposium on public affairs held on ursday evening, F. J. Chesterman, chair-an, several important questions engaging e attention of the administration and the tion were discussed, such as social secu-y, old age and unemployment compensa-on, industrial co-operation with and with-t government supervision, conservation natural resources, national, state, and cal public works activities and rural elec-ification. The speaker on social security as Arthur J. Altmeyers, of the Social curity Board. Colonel E. W. Clark, ecutive assistant, Public Works Adminis-ation, in his address, made a plea for eater social-mindedness in engineers. his discussion of natural resources, omas R. Tate, chief, power resources vision, Federal Power Commission, dis-ayed numerous large-scale maps of power stems in the United States, including one owing the geographical regions into which is proposed to divide the nation for rposes of power production and distribu-on.

eports of Committees

At the business session on Friday morning, . A. Potter presiding, a roll call of repre-ntatives was followed by the president's ldress, and reports of the executive secre-ry, treasurer, and numerous operating mmittees.

President Potter spoke briefly on the forts Council had made during the year to courage the activities of the committees d to co-ordinate the work of engineering cieties. He spoke of the need for more ctual data on the impart of technology on cial security and urged the active support Council in efforts to assist in their deter-ination and dissemination, in the hope at the public more generally may come to gard engineering and the engineer in their ue economic and social significance.

Mr. Feiker read a report which covered e varied and important work of Council d its numerous committees. Unfortu-ately, limitations of space forbid even a mmary of Mr. Feiker's report, but plans e under consideration to bring Council's tivities before the readers of Electrical ngineering in later issues.

The report of the treasurer showed suc-ssful operation of Council's financial fairs within the income received and a lance of approximately $2,000 to carry er into 1937. A budget of estimated penditures for 1937, amounting to $39,-1 was adopted. Reports were presented publicity, membership and representa-on, regional activities, finance, constitu-on and by-laws, and nominations.

Abel Wolman, chairman of the water sources committee, addressed the assembly ncheon on the engineer's opportunities and sponsibilities in the conservation of tural resources.

Mr. Wolman's excellently delivered ad-ess reviewed the steps by which, from the essure of PWA activities, and the work of e Mississippi Valley committee and the ater planning board the water resources committee was evolved. He described briefly some of the more important principles of action of the water resources committee. One was the development of co-ordinated national water plans. Another was that national water development concerned people primarily, rather than merely water. It was necessary, he said, to effect a centralization of points of view on a river basin as a whole in order to obtain a necessary perspective. He then described briefly some specific undertakings of the committee and the work of several subcommittees that experience had shown that it was necessary to organize.

Following the luncheon, reports of numerous public-affairs committees of AEC were presented. F. J. Chesterman presided.

Although it is impossible to summarize the numerous reports presented, it may be stated that extensive discussions followed the presentation of the reports on patents, R. S. McBride, chairman; public works, Alonzo J. Hammond, chairman; rural electrification, L. F. Livingston, chairman; conservation and utilization, Leonard J. Fletcher, chairman, and surveys and maps, John S. Dodds, chairman. These reports were accepted and referred to the executive committee for action.

Morris L. Cooke, administrator, Rural Electrification Administration, spoke on the achievements of the REA which he characterized as "rural electrification in spite of the experts." His 3 levels of interest in the work, were, he said, (1) that of "gadgets," the electrical devices themselves, (2) that of the "cultural renaissance for agriculture," and (3) national survival as threatened by unwise use of soil and water.

"All Engineers' Dinner"

As usual, the high point of the AEC annual assembly was the "all engineers' dinner," held on the night of January 15 with about 450 in attendance and President A. A. Potter presiding. A reception preceded the dinner. A feature of the dinner program was the presentation of honorary membership of the ASME to Admiral Cone, retired, of the United States Navy.

Acting as toastmaster was Colonel D. H. Sawyer, director, Federal Employment Stabilization Board, who introduced Messrs. Angevine, Bickelhaupt, MacCutcheon, Mead, Coleman, Feiker, and Blasinghame and spoke on the construction during the depression.

Admiral Cone was presented by M. X. Wilberding, chairman of the ASME Washington section. In introducing Admiral Cone, Mr. Wilberding spoke briefly of his naval career.

In responding to the speech of presentation by J. H. Herron, president of the ASME, Admiral Cone expressed his appreciation of the honor done him, and said that he would maintain the high standards set by those distinguished engineers who had previously been elected to honorary membership in the ASME.

The principal addresses at the dinner were by Rear-Admiral Harold J. Bowen, engineer-in-chief of the United States Navy, who spoke on national defense, by Hon. J. C. O'Mahoney, senator from the State of Wyoming, on the interstate regulation of business by federal license, and by C. F. Hirshfeld, whose subject was the engineer's responsibilities in social and economic questions. Because of Mr. Hirshfeld's illness his address was read by R. L. Sackett.

Admiral Bowen said that a modern navy is highly mechanized and depends on the engineer for maintenance, and called attention to the diversity and extent of the vessels, aircraft, shore establishments, and communication systems of which it is comprised. He gave many examples of the stimulation to naval engineering coming from industry, as well as that received by industry from the Navy. In closing he asserted that naval defense is a struggle between applied science as utilized by the combatants and that a navy cannot rise above the level of the engineering development of the nation to which it belongs.

In his penetrating and carefully reasoned address Mr. Hirshfeld urged the engineer to enlarge the sphere of his influence by accepting a larger measure of responsibility in solving social and economic problems resulting from the impacts of applied science. He made a plea for a factual study of such grave questions as technological unemployment, relative returns to capital and labor of the fruits of industry, and competition. As examples of public questions in which engineers might interest themselves in their own communities as a public service he mentioned traffic regulation, air pollution, noise abatement, and public transportation. He closed by asking whether or not the engineer would have the fortitude to serve humanity in the future in the same grand manner in which he had served it on technological matters in the past.

Senator O'Mahoney gave numerous examples of corporation created under the laws of a single state which do business in several or all states and in world trade, and argued that there exists a need for the regulation of interstate business by means of federal licenses. He explained some of the principal features of a bill before the Congress introduced by him as a device for the regulation he proposed.

Session on Engineering Economics

Continuing its meeting on Saturday morning with a session on engineering economics, the assembly listened to further reports. Mr. Chesterman made a plea for engineers to take a broader view of their profession in line with the thoughts expressed in Mr. Hirshfeld's address at the dinner, and had a discussion on effective publicity on engineers and their work.

C. E. Stephens reported for several of the united action committees; and a resolution was passed in favor of an extension of the merit system.

In presenting a report of the engineering economics committees Ralph E. Flanders reviewed the status of the third progress report of the committee on consumption, economics, and distribution. For the committee on special surveys and studies he made the proposal, which was referred to the executive committee by vote of the assembly, that Council bring about co-operation between its engineering economics committees and social-science groups.

J. Frederic Dewhurst, of the committee on social security of the Social Science Research Council, spoke briefly on social science and engineering. The engineering profession, he said, was in a position to make a con-

tribution to the preventive side of social security.

Officers elected at the assembly meeting were, for vice-presidents C. O. Bickelhaupt, and John S. Dodds, representing the state and local member organizations. C. E. Stephens was elected treasurer. In all cases these were re-elections. The term of president is for 2 years, and as Dean Potter has served but one, he will continue in that office for 1937. Representatives and alternates to the assembly were also elected from the 6 geographical districts into which AEC membership organizations are divided. F. M. Feiker was re-elected executive secretary. Chairmen of committees selected were William McClellan, finance; C. O. Bickelhaupt, membership and representation; and F. J. Chesterman, public affairs.

Letters to the Editor

CONTRIBUTIONS to these columns are invited from Institute members and subscribers. They should be concise and may deal with technical papers, articles published in previous issues, or other subjects of some general interest and professional importance. ELECTRICAL ENGINEERING will endeavor to publish as many letters as possible, but of necessity reserves the right to publish them in whole or in part, or reject them entirely.

ALL letters submitted for consideration should be the original typewritten copy, double spaced. Any illustrations submitted should be in duplicate, one copy to be an inked drawing but without lettering, and other to be lettered. Captions should be furnished for all illustrations.

STATEMENTS in these letters are expressly understood to be made by the writers; publication here in no wise constitutes endorsement or recognition by the American Institute of Electrical Engineers.

An Analysis of Electrical Engineering Graduates

To the Editor:

In the article, "An Analysis of Electrical Engineering Graduates," which appeared on pages 952–3 of the September issue of ELECTRICAL ENGINEERING, Brown University, at Providence, R. I., unfortunately was omitted from the list of American colleges offering a 4-year course in electrical engineering, leading to a degree of bachelor of science in electrical engineering or its equivalent. Since the publication of that article, information from Duke University, Durham, N. C., also has been made available.

Students at Brown who specialize in electrical engineering receive the degree of bachelor of science in engineering on completion of the 4-year course. Following are the numbers of graduates who specialized in electrical engineering at Brown during the period of the survey: 1927–28—14; 1928–29—13; 1929–30—11; 1930–31—6; 1931–32—5; 1932–33—12; 1933–34—11; 1934–35—9.

Duke University, which offers a 4-year course leading to the degree of bachelor of science in electrical engineering, graduated the following numbers of electrical engineers: 1927-28—2; 1928–29—6; 1929-30—3; 1930-31—5; 1931-32—4; 1932–33—10; 1933-34—13; 1934-35—11.

Very truly yours,

CLIFFORD A. FAUST (A'35)

President, National Executive Council,
Eta Kappa Nu Association;
In Charge of Power Utility
Division of Advertising,
Ohio Brass Company, Mansfield

Preparation of Institute Papers

To the Editor:

We note your interest in readers' comments on the new paper and format of ELECTRICAL ENGINEERING. The new page is indeed pleasing and easier to read. We regret, however, that you are now breaking up the continuity of articles in the usual magazine fashion. The continuation of articles on back pages, fostered by editors chiefly in order to take the reader into the advertising columns of ordinary magazines, is a nuisance which is probably unnecessary in a publication of this type.

At various times instructions are issued regarding the methods of preparing papers for the Institute. We feel that a few comments might be pertinent at this time.

It might be presumed that Institute papers, while of greater interest to the specialist in whose field they are written, are also to be read by many with a normal curiosity and the desire to keep informed in related subjects, even though the mathematics may be unfamiliar. Papers might better be written with the idea more clearly in mind that the reader knows less about the subject than the writer, and that the time and effort of the former are to be conserved as much as possible. Several suggestions can be made as an aid to easier reading.

Even though the aim of the paper might be well presented in the introduction, the reader can follow the processes much more readily if the aim of each step in the development of the paper is presented in a brief statement. This, combined with shorter paragraphs and more frequent subtitles, is a great aid to rapid scanning and easier grasp.

The reader who expects to make use of the material presented, would be aided if more careful attention were given to the following considerations:

1. More adequate definition of symbols and terms used. If they are obscure, a brief background or more complete references would be useful. (Many symbols are not adequately defined by the title, as for instance, "synchronous reactance.") Understanding of differential equations is frequently aided by identifying the type to which they belong with a brief statement of the manner of solution.

2. "Word derivations" of equations are helpful. Lack of space may frequently make complete mathematical development inadvisable. Yet if the equation is important to the material at hand, the primary assumptions on which it is based and an outline of the steps followed could be given in a brief paragraph. Such explanations are especially necessary if simplifying assumptions have be[en] made in the development.

3. Time and wasted effort could be saved t[he] reader if more care were taken to indicate (wh[en] known) the limitations of various data. This [is] especially true when the exact process of obtaini[ng] data is not given and the user has small opportuni[ty] of determining the inherent limitations.

4. Many Institute papers would be greatly i[m]proved if the author kept more firmly in mind th[at] he must avoid the slightest suspicion of aimi[ng] at a display of his own erudition rather than [to] present the reader with interesting and usef[ul] information.

Several years ago Professor Karapeto[ff] made the prediction that the time woul[d] come when electrical engineers would co[n]cern themselves more with the fundament[al] nature of classical vector theory. Pape[rs] presented before the Institute for the pa[st] year indicate that this prediction wa[s] justified.

In view of the present growth of suc[h] application and its probable continuatio[n] it might be well through adequate definitio[n] to avoid the confusion which may readil[y] arise. Classification of a term as a *vect[or]* may no longer be an identification at al[l] when one considers that the writer may hav[e] in mind the complex number vector, thos[e] of classical vector analysis, those based o[n] the work of Hamilton, of Gibbs-Wilson or the more modern concepts and variation[s] of them associated with certain forms o[f] tensor analysis, the complex vector o[f] A. Pen-Tung Sah, etc.

It would be well to remember that ex[]periments (and this might hold for mathe[]matical developments as well) are accepte[d] by science only if they are susceptible t[o] reproduction. Hence, while one may hav[e] no reason to doubt that a writer has ob[]tained the results or made the analyses h[e] claims, nevertheless, through inadequat[e] definition of symbols, unannounced assump[]tions in his derivations, and a presentatio[n] not aimed to be of maximum value to th[e] reader, the latter may frequently be unabl[e] to reproduce the work presented. Suc[h] reproduction is necessary to progressiv[e] growth and development of a science.

Very truly yours,

A. F. PUCHSTEIN (A'20, M'27
Chief Engine[er]

T. C. LLOYD (A'31
Development Engine[er]
Robbins & Myers, Inc
Springfield, Ohi[o]

Electrical Engineering's New "Easy-Reading Page"

To the Editor:

. . . You are to be congratulated on th[e] makeup of the January 1937 issue of ELEC[]TRICAL ENGINEERING. I admit my firs[t] reaction to the cream-colored paper wa[s] negative. However, as I sat in my specia[l] chair last evening reading your "easy reading page" under our IES lamp, [I] found my technical reading to be a pleasur[e] indeed. I hope you do not go back to th[e] white paper. I find this paper very muc[h] more restful, for my eyes are quite sensi[]tive to glare. Listing the author and titl[e] at the bottom of each page is an improve[]ment. The 2 pages which include the be

nning of an article always have an uncanny way of sticking together. The titles and page numbers are so much more convenient at the bottom than they would be at the top. When this information is given at the top, one either must open the magazine wide or lean halfway across the desk. I'm sorry that I can't offer any constructive criticism. You are too far ahead of me . . .

Very truly yours,

V. P. Hessler (A'29)

Instructor in Electrical Engineering, Iowa State College, Ames

To the Editor:

. . . The new style paper appeals to me, since it seems to hold what was promised, elimination of glare. I believe the carrying over of the name of author and abbreviated title on all pages of the papers will help considerably in locating desired references.

Very truly yours,

J. H. Hagenguth (A'28)

Electrical Engineer, High Voltage Engineering Laboratory, General Electric Company, Pittsfield, Mass.

To the Editor:

As one whose eyes are sensitive to glare, due undoubtedly to poor lighting and "hard-reading pages" in youth, I want to commend you most heartily on the adoption of the "easy-reading page."

Very truly yours,

Frederick Holmes (A'22, M'27)

President, Duncan Electric Manufacturing Company, Lafayette, Ind.

To the Editor:

. . . I think that a very great improvement has been made in the general style and make-up . . .

Very truly yours,

A. S. Langsdorf (A'03, F'12)

Dean of the Schools of Engineering and Architecture, Washington University, St. Louis, Mo.

To the Editor:

I find that the new "easy-reading page" is exactly that. I hope that you will continue to use it.

Willis W. Snyder (A'35)

Meter Department, Niagara Alkali Company, Niagara Falls, N. Y.

To the Editor:

I wish to comment very favorably on the change you have just made in the paper on which Electrical Engineering is printed. The light buff color is far easier on the eyes and under artificial light the glare is reduced almost to the vanishing point.

Also I like very much your initial page entitled "High Lights." It is an excellent idea to have a brief summary of this sort given first. One can see at a glance what articles are of most interest and will then be induced to look them up and read them more thoroughly.

I certainly hope that both of these features are continued.

Yours very truly,

R. W. Warner (M'28)

Professor and Head of the Department of Electrical Engineering, University of Kansas, Lawrence

To the Editor:

I would like to register enthusiastic approval of the new type and tinted paper used in Electrical Engineering. I think the paper color very well chosen since the temptation usually is to use too yellow a stock.

Very truly yours,

L. J. Buttolph (M'36)

Electrical Engineer, General Electric Vapor Lamp Company, Hoboken, N. J.

To the Editor:

May I add my word of approval of your continued efforts to make Electrical Engineering the best possible kind of publication?

The "easy-reading page" which you present with the January issue is, in my opinion, a significant contribution of the electrical engineering profession to human welfare. There is no doubt but what this sort of thing has long been needed, and I trust that continued efforts may be fruitful along this line.

Sincerely yours,

M. S. Coover (A'16, M'32)

Head of Electrical Engineering Department, Iowa State College, Ames

To the Editor:

I was very much interested in your easily read page which appeared in the January 1937 issue of Electrical Engineering. . . all comments which I have heard have been favorable. . . After I had gotten over my first unfavorable impression of seeing the yellowed edges of the sheets before the book was opened, I liked it very much. . . .

Very truly yours,

Willard Champe (A'25, M'35)

Electrical Engineering Department, The Commonwealth & Southern Corporation, Jackson, Mich.

Personal Items

Asger Vilstrup (A'20, M'27) chief electrical engineer, British Columbia Electric Railway Company, Ltd., has been elected president of the Engineering Profession in British Columbia for the year 1937. Mr. Vilstrup was born at Borris, Denmark, in 1884, and received his technical education at the College of Electrical Engineering, in Copenhagen, Denmark. Upon completion of his studies, he was employed by several

ASGER VILSTRUP

electrical companies in England, including British Insulated and Helsby Cables, Ltd., during the period 1903–09. In 1911 Mr. Vilstrup went to Canada to become field draftsman and subforeman on hydroelectric construction at Lake Buntzen for the British Columbia Electric Railway Company, Ltd. Three years later he was made assistant engineer in the electrical department of that company at Vancouver. In that position he was engaged in the design of substations and transmission and distribution lines, and in the maintenance of the power plant and distribution systems. In 1929 Mr. Vilstrup was appointed assistant plant manager, and during the year 1935–36 was acting plant manager. He was made chief electrical engineer in 1936. He has been active in the affairs of the Institute's Vancouver Section for several years (chairman 1925–26) and was active in the arrangements and administration of the AIEE Pacific Coast convention held at Vancouver in 1932.

P. S. Millar (A'03, M'13) president, Electrical Testing Laboratories, Inc., New York, N. Y., was elected president of the United States National Committee of the International Commission on Illumination at the recent annual meeting of the Committee. Mr. Millar was born at Andover,

P. S. MILLAR

N. J., in 1880, and obtained his formal technical eduction at Paterson Classical and Scientific School and through the International Correspondence Schools. In 1897 he entered the employ of the Lamp Testing Bureau (now Electrical Testing Laboratories, Inc.) and in 1899 became assistant

manager of that company. He became general manager in 1914, and has been president since 1930. Mr. Millar has done much original work in illumination research, being co-inventor of the Sharp-Millar photometer, and has contributed liberally to the technical press. He has been a member of the Institute's committees on electrophysics, 1917–18; meetings and papers (now technical program), 1925–28; and a member since 1924 and chairman from 1925 to 1928 of the committee on production and application of light. Mr. Millar is a fellow of the American Physical Society, member of the council of the Association of Consulting Chemists and Chemical Engineers, secretary-treasurer of the Association of Edison Illuminating Companies, member and past-president of the Illuminating Engineering Society, and director of the Thomas Alva Edison Foundation.

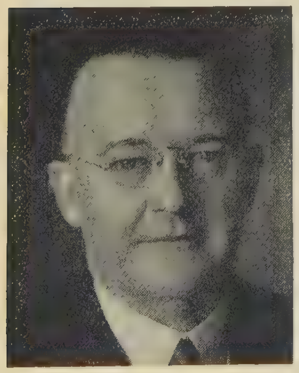
William Kelly (F'25) formerly president of the Buffalo, Niagara, and Eastern Power Corporation, recently was elected president of the Niagara, Lockport, and Ontario Power Company. Colonel Kelly was born in New York, N. Y., in 1877, attended the Sheffield Scientific School of Yale University, and was graduated from the United States Military Academy in 1899. During 1902–03 he pursued graduate work in the U.S. Army Engineer School of Application. Upon graduation in 1899, Colonel Kelly was placed in charge of design of electrical installations for sea coast defenses. He continued to serve in that capacity, and concurrently (1906–10) as assistant engineer commissioner of the District of Columbia, until 1913. During the World War he served as chief engineer of the 42nd Division and Fourth Army Corps, and reported for the peace conference on several rivers that were internationalized. When the Federal Power Commission was organized in 1920, Colonel Kelly was appointed its chief engineer and, while serving in that capacity, presented a report on the Colorado River as a source of hydroelectric power and irrigation supply. He was also an active member of the superpower committee for the northeastern area of the United States and a member of the American section of the International Board of Engineers, investigating the St. Lawrence waterway project. In 1925 he was appointed director of engineering of the National Electric Light Association, and in the following year became affiliated with the Buffalo, Niagara, and Eastern Power Corporation. Colonel Kelly became president of that company in 1933. He is a member of the Society of American Military Engineers and the American Society of Civil Engineers; he received the James Laurie prize of the latter society in 1925.

H. M. Sharp (M'34) superintendent of the Huntley stations, Buffalo General Electric Company, Buffalo, N. Y., has been elected a vice-president of the Buffalo, Niagara, and Eastern Power Corporation. Mr. Sharp was born at Buffalo, N. Y., in 1892, and received the degree of mechanical engineer at Cornell University in 1915. Following his graduation, he served briefly as an instructor in mechanical engineering at Cornell University, as an assistant engineer with the Bethlehem Steel Company, Lackawanna, N. Y., and with the U.S. Army, before becoming efficiency engineer at Huntley station in 1919. In 1926 he accepted a similar position with the Indiana Electric Corporation, Terre Haute, Ind., but returned to the Buffalo General Electric Company in 1928 as assistant chief engineer of Huntley station. On completion of the second Huntley station, Mr. Sharp was made assistant superintendent of both stations in 1930; in 1931 he became superintendent, which position he has held for the last 6 years.

N. R. Gibson (M'32) vice-president of the Buffalo, Niagara, and Eastern Power Corporation, Buffalo, N. Y., has been appointed vice-president of the Buffalo General Electric Company and the Niagara, Lockport, and Ontario Power Company, and director of the Niagara Electric Service Corporation. Mr. Gibson was born at Guelph, Ont., Canada, in 1880, and was graduated from the University of Toronto in 1901, with a diploma in mechanical and electrical engineering; in 1904 he received the degree of bachelor of arts and sciences, and in 1931 the honorary degree of doctor of engineering at the same institution. Following his graduation in 1904 he served briefly with several contracting companies before becoming associated (1908) with Smith, Kerry, and Chase, consulting engineers in Toronto, Ont., Canada, where he was in charge of the civil and hydraulic department. During 1913–15 Mr. Gibson served as consulting engineer to the Ontario Power Company, Niagara Falls, Ont., and the Electric Power Company, Ltd., Toronto; later, he served as chief engineer for the Ontario Power Company, 1915–16, and assistant chief engineer of the Electric Power Company, 1916–17. From 1918 to 1925 he was hydraulic engineer of the Hydraulic Power Company (now Niagara Falls Power Company), Niagara Falls, N.Y., later serving as executive engineer, chief engineer, and vice-president and chief engineer; concurrently he was vice-president and chief engineer of the Buffalo, Niagara, and Eastern Power Corporation and vice-president of the Niagara Hudson Power Corporation, New York, N. Y. Mr. Gibson is a member of the American Society of Civil Engineers and The American Society of Mechanical Engineers.

L. T. Blaisdell (A'20, M'22, vice-president) southwestern district manager, General Electric Company, Dallas, Texas, has been elected a commercial vice-president of the company. Mr. Blaisdell was born at Carlisle, Mass., in 1886, and following his graduation from the Massachusetts Nautical Training School, in 1904, he entered the employ of the General Electric Company as a student engineer at Lynn, Mass., where he remained until 1907. During the period 1907–11 he served as construction engineer, in which capacity he supervised the installation of power-plant equipment on many naval vessels built along the Atlantic coast and served as engineer on many trial trips. From 1911 to 1917 he served as commercial engineer in the Baltimore, Md., offices of the General Electric Company, and in 1917 was transferred to the Washington, D. C., offices to follow various activities of the federal government. He served in that position until 1923 when he was transferred to Dallas as southwestern district manager. Mr. Blaisdell was chairman of the AIEE Washington Section, 1922–23, and of the Dallas Section, 1930–31.

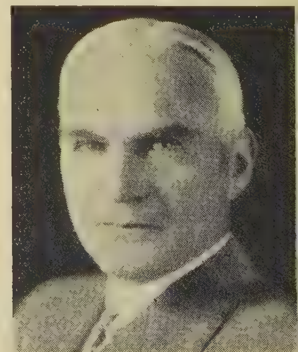
R. B. Howland (A'11, M'22) formerly assistant to the president of United Engineers & Constructors, Inc., Philadelphia, Pa., recently was elected a vice-president and director of that company. Mr. Howland was born at Marion, Mass., in 1885, and received the degrees of bachelor of arts (1906) and bachelor of science in electrical engineering (1910) at Drury College and Purdue University, respectively. Following his graduation in 1910, he became associated



L. T. BLAISDELL

WILLIAM KELLY

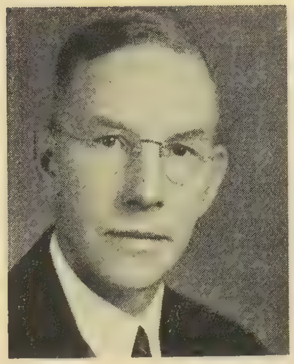
R. B. HOWLAND



N. R. GIBSON

M. O. TROY

F. M. FARMER



H. J. MAC LEOD

E. D. UHLENDORF

with the Stone and Webster Company, first as an electrician and switchboard operator for the Pacific Coast Power Company, Sumner, Wash., and later as assistant general superintendent of the Mississippi River Power Company, Keokuk, Iowa. In 1917 Mr. Howland accepted a position as superintendent of power, and subsequently as superintendent of power and utilities, with the American International Shipbuilding Corporation, Hog Island, Pa. He returned briefly to the services of the Mississippi River Power Company in 1919, and then became affiliated with Dwight P. Robinson & Co., Inc., New York, N. Y., as assistant electrical engineer. When Dwight P. Robinson & Co. was merged with 3 other engineering organizations to form United Engineers & Constructors, Inc., in 1929, Mr. Howland was made assistant to the president of the new organization, and has held that position since. He is a member of Tau Beta Pi.

M. O. Troy (A'08, M'12) manager of the central station department, General Electric Company, Schenectady, N. Y., has been elected a commercial vice-president of the company. Mr. Troy was born at Burlington, N. C., in 1872, and received the degree of bachelor of science in electrical engineering at the University of Virginia in 1896, following which he entered the employ of the General Electric Company as a test engineer. He was transferred to the West Lynn works of that company as foreman of transformer test in the following year, and in 1898 became associated with Prof. Elihu Thomson (A'84, M'91, F'13, HM'28, Edison Medalist '09, past-president) in development work on constant-current transformers. In 1901 Mr. Troy was made assistant engineer of the a-c engineering department of the West Lynn works and was later transferred to the transformer sales department. In 1907 he became manager of sales of transformers, lightning arresters, and voltage regulators, and in 1923 was appointed executive assistant manager of the central station department. Mr. Troy became manager of the department in 1928.

P. H. Thomas (A'00, F'12, past vice-president, member for life) formerly chief of the power requirements division, National Power Survey, Federal Power Commission, Washington, D. C., has been appointed regional director of the Commission, with offices at Atlanta, Ga. Mr. Thomas was born at Boston, Mass., in 1872, and received the degree of bachelor of science in electrical engineering at the Massachusetts Institute of Technology in 1893. Following his graduation, he entered the engineering department of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., where his work consisted of lightning-arrester and high-voltage engineering, and remained with that company until 1903, when he became chief engineer of the Cooper-Hewitt Electric Company. In 1907 Mr. Thomas established his own consulting engineering offices at New York, N. Y., and continued his private practice until he was appointed consulting electrical engineer to the firm of Guggenheim Brothers, in 1916. In 1928 he re-established his own consulting engineering offices, continuing until he was appointed chief of the power requirements division of the National Power Survey in 1934. Mr. Thomas was manager of the Institute, 1907–10; vice-president, 1910–12; and has been a member of the committees on electrophysics, meetings and papers (now technical program), standards, power transmission and distribution, award of Institute prizes, Lamme Medal, and Edison Medal. He is a member of The American Society of Mechanical Engineers.

E. D. Uhlendorf (A'13) formerly a member of the operating committee, Byllesby Engineering and Management Corporation, Chicago, Ill., has been appointed executive engineer of Public Utility Engineering and Service Corporation, successor to the Byllesby company. Mr. Uhlendorf was born at Chicago in 1887, and attended the Armour Institute of Technology, specializing in civil engineering. He has been associated with Public Utility Engineering and Service Corporation and its predecessor continuously since 1911, with the exception of a 3-year period during which he was engaged in special public utility evaluation work. He has had charge of many important appraisal projects for rate making and security issues, and has appeared as expert witness before several commissions and courts. Mr. Uhlendorf became a member of the operating committee of the Byllesby Engineering and Management Corporation in 1925. He is a member of the American Society of Civil Engineers and the Society of American Military Engineers.

F. M. Farmer (A'02, F'13, director) vice-president and chief engineer of the Electrical Testing Laboratories, Inc., New York, N. Y., has been elected chairman of the standards council of the American Standards Association for the year 1937. Mr. Farmer was born at Ilion, N. Y., in 1877, and was graduated from Cornell University in 1899. In 1903, after spending a year in the test department of the General Electric Company and $2^1/_2$ years in the inspection division of the U.S. Navy at the Brooklyn (N. Y.) Navy Yard, he joined the staff of the Electrical Testing Laboratories, Inc., then known as the Lamp Testing Bureau. Mr. Farmer has been active in various phases of ASA work, as chairman of 2 sectional committees and member of 2 others, and as a member of the electrical standards committee and the United States National Committee of the International Electrotechnical Commission. In addition, he is active in Institute affairs, having been member or chairman of many of the technical committees, and is at present a member of the board of directors. Since 1935 he has been Institute representative on the Engineering Foundation board and on the engineering societies monograph committee. Mr. Farmer is a past-president of the American Welding Society and of the American Society for Testing Materials, a fellow of the American Association for the Advancement of Science, and a member of the Institution of Electrical Engineers and The American Society of Mechanical Engineers.

H. J. Mac Leod (A'23) formerly professor of electrical engineering, University of Alberta, Edmonton, Canada, has been appointed head of the department of mechanical and electrical engineering at the University of British Columbia, Vancouver. Professor Mac Leod was born at New London, Prince Edward Island, in 1887, and received the degrees of bachelor of science (1914) and master of science (1916) from McGill University and the University of Alberta, respectively. In 1921 he received the degrees of master of arts and doctor of philosophy at Harvard University. Following his graduation from McGill University, he served for 2 years as lecturer in electrical engineering at that institution, and after 3 years' (1916–19) army service, entered Harvard University to pursue graduate work in electrical physics. In 1921 he was appointed associate professor of electrical engineering at the University of

A. L. JONES

E. H. GINN

J. M. COSTELLO

T. S. KNIGHT

Alberta and in 1924 professor of electrical engineering. He is a member of the Engineering Institute of Canada.

T. S. Knight (A'05) New England district manager, General Electric Company, Boston, Mass., has been elected a commercial vice-president of the company. Mr. Knight was born in Massachusetts in 1882, and was graduated from Tufts College in 1903, with the degree of bachelor of science in electrical engineering. Following his graduation, he entered the testing department of the Stanley Electric Company, and in the following year was transferred to the switchboard engineering department. When the Stanley Electric Company became a part of the General Electric Company, Mr. Knight was retained in the switchboard engineering department at the Schenectady, N. Y., works of the new company. In 1908 he was transferred to the Boston, Mass., offices of the General Electric Company, and placed in charge of switchboard engineering there. He has been New England district manager since 1926.

A. L. Jones (A'07, M'26) Rocky Mountain district manager, General Electric Company, Denver, Colo., has been elected a commercial vice-president of the company. Mr. Jones was born at Balston, N. Y., in 1879, and received the degree of mechanical engineer in electrical engineering at Cornell University in 1904. Upon graduation, he entered the testing department of the General Electric Company, at Schenectady, N. Y., continuing as a test engineer until he was transferred to the power and mining engineering department in 1906. In 1909, Mr. Jones was transferred to the Denver offices of the General Electric Company as district engineer, in which capacity his work consisted of engineering supervision of construction and construction contracts. He was appointed district manager in 1928.

J. M. Costello (A'27) vice-president and general manager, The Syracuse Lighting Company, Inc., Syracuse, N. Y., has been elected a vice-president of the Niagara, Lockport, and Ontario Power Company. Mr. Costello was born at Clyde, N. Y., in 1891, and has been affiliated with the Niagara, Lockport, and Ontario Power Company, and its associated companies, since 1911. During his service of more than 25 years, he has acted as division superintendent and as district manager of that company; also as district manager and as general manager of the Livingston-Niagara Power Company. Mr. Costello was made executive manager of the Niagara, Lockport, and Ontario Power Company in 1928, and vice-president and general manager of The Syracuse Lighting Company in 1930.

E. H. Ginn (A'03) southeastern district manager, General Electric Company, Atlanta, Ga., has been elected a commercial vice-president of the company. Mr. Ginn was born at Worcester, Mass., in 1878, and was graduated from the Worcester Polytechnic Institute in 1900. Following a year's graduate study at the same institution, he entered the testing department of the General Electric Company, Schenectady, N. Y., and after a brief service as test engineer was transferred to the railway engineering department in the Atlanta offices of that company. He was appointed district sales manager in 1918 and district manager in 1922.

Thomas Fitzgerald (A'02) vice-president and general manager, Pittsburgh (Pa.) Railways Company, has been elected a member of the board of directors of the Philadelphia Company. Mr. Fitzgerald is a native (1878) of Baltimore, Md., and a graduate of The Johns Hopkins University in the class of 1898. Following his graduation, he entered the employ of the Baltimore and Ohio Railroad Company as an inspector, and after serving with several companies, eventually became general manager of the Cincinnati (Ohio) Traction Company in 1913. In 1917 he resigned that position to join the U.S. Army, and following the World War Mr. Fitzgerald established his own consulting engineering offices at Pittsburgh, Pa. In 1924 he became vice-president of the Pittsburgh Railways Company, and later vice-president and general manager.

L. S. Boggs (A'93, M'98, member for life) service engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., has retired from active service. Mr. Boggs was born at Lafayette, Ind., in 1867, and was graduated from Purdue University in 1888 with the degree of bachelor of mechanical engineering; in 1892 he obtained the advanced degree of mechanical engineer from the same institution. Following his graduation in 1888, he entered the employ of the Sprague Electric Railway Company, remaining there until 1891. After a year of graduate study, Mr. Boggs was appointed engineer of power for the Columbian Exposition at Chicago, Ill., in 1893 and in 1894 he held a similar position at the Cotton States and International Exposition at Atlanta, Ga. In 1896 he became superintending engineer for the Pioneer Electric Power Company, Ogden, Utah, where he remained for 4 years before becoming associated with Sargent and Lundy, Inc., Chicago, Ill. Mr. Boggs has been associated with the Westinghouse company since 1904, having started as a construction engineer. He took an active part in many major railway electrification projects, both in the United States and in South America.

E. W. Judy (A'26) vice-president of the Duquesne Light Company, Pittsburgh, Pa., recently was elected a member of the board of directors of the Philadelphia Company. Following a 3-year preliminary training, Mr. Judy became associated with the Stone and Webster Company at Seattle, Wash., in 1909, where he remained until 1914, when he became superintendent of construction for the Southern Sierras Power Company, Riverside, Calif.; later he became local superintendent and district manager for that company. In 1923 he joined the Duquesne Light Company as superintendent of overhead lines, subsequently becoming superintendent of the distribution department, operating manager, and vice-president.

E. F. Nuezel (A'27) formerly underground transmission and distribution engineer, Union Gas and Electric Company, Cincinnati, Ohio, has become superintendent of the underground department of the Cincinnati Gas and Electric Company. Mr. Nuezel is a native of Cincinnati, and an electrical engineering graduate of the University of Cincinnati. Upon graduation, he entered the electrical distribution department of the Union Gas and Electric Company in 1922 as assistant engineer on maintenance and construction. In 1927 he joined the engineering staff of the Colum-

bia Engineering and Management Corporation as assistant engineer on engineering planning, but later returned to the Union Gas and Electric Company as underground transmission and distribution engineer.

L. O. Dorfman (A'19, M'28) manager of the engineering division, Westinghouse Electric & Manufacturing Company, Cincinnati, Ohio, has been made engineering manager of the New England district of that company, with offices at Boston, Mass. Mr. Dorfman was born at Pittsburg, Texas, in 1892, and received the degree of electrical engineer at the University of Texas in 1916. He entered the employ of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., immediately following his graduation, and his service with that company has been uninterrupted, except for a period of service with the U.S. Army during the World War. He was transferred to the Cincinnati offices of the Westinghouse company in 1927.

A. H. Morton (A'24) National Broadcasting Company, New York, N. Y., has been appointed manager of the department of managed and operated stations of the National Broadcasting Company. Mr. Morton is a native (1895) of Chicago, Ill., and an engineering graduate of the University of Illinois. During 1917–19 he served in the U.S. Army, and following his resignation was associated with the General Electric Company for 2 years before joining the Radio Corporation of America as manager of the Washington, D. C., offices of that company. In 1923 Mr. Morton was transferred to the New York, N. Y., offices as head of the commercial department of RCA Communications, and in 1929 was made European manager for the Radio Corporation of America.

D. S. MacCorkle (A'30) has resigned as cable engineer in the engineering department of the New York and Queens Electric Light and Power Company, Flushing, N. Y., and is now associated with the Habirshaw Cable and Wire Corporation, Yonkers, N. Y., as a sales engineer. Mr. MacCorkle is a native (1905) of Flushing, N. Y., and an electrical engineering graduate of Washington and Lee University. Upon graduation, he entered the student training course of the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., in 1926. After spending a year as a sales engineer for the Westinghouse company, he accepted a position as assistant engineer for the New York and Queens Electric Light and Power Company in 1928.

J. E. M. Mitchell (A'27) formerly southern district sales manager, Jeffrey DeWitt Insulator Company, Kenova, W. Va., has been advanced to the position of general sales manager of the company. Mr. Mitchell is a native (1890) of Edisto Island, S. C., and an electrical and mechanical engineering graduate of Clemson College. Following his graduation, he entered the employ of the General Electric Company, Schenectady, N. Y., as a test engineer, and for a time served under Dr. C. P. Steinmetz. Mr. Mitchell served briefly with several companies, and with the U.S. Army Corps of Engineers, before becoming southern district sales manager for the Jeffrey DeWitt Insulator Company in 1924.

H. W. Eales (A'17, F'25, past vice-president) who has been chief electrical engineer of the Byllesby Engineering and Management Corporation, Chicago, Ill., has been appointed chief electrical engineer of the Public Utility Engineering and Service Corporation, Chicago, successor to the Byllesby organization. Mr. Eales has been active in Institute affairs, having been a member of many of the technical committees and a vice-president (1921–26) representing the South West District. He has also been active in committee work of the Edison Electric Institute and the Association of Edison Illuminating Companies, and is a member of Phi Beta Kappa and Sigma Xi.

G. H. Jump (A'18, M'30) engineer in the Buffalo, N. Y., offices of the General Electric Company, has been appointed New England district engineer for the company, with headquarters at Boston, Mass. Mr. Jump was born at Binghamton, N. Y., in 1888, and received the degree of electrical engineer at Syracuse University in 1910. Immediately following his graduation, he entered the employ of the General Electric Company, Schenectady, N. Y., as a student engineer and has since been associated with that company in various capacities. He was transferred to the Buffalo offices in 1916 and was appointed engineer in charge in 1918.

R. A. Jones (A'20) engineer in the Syracuse, N. Y., offices of the General Electric Company, has been transferred to the Buffalo, N. Y., offices in a similar capacity. Mr. Jones is a native (1892) of Wabasha, Minn., and an electrical engineering graduate (1916) of the University of Minnesota. Upon his graduation, he entered the testing department of the General Electric Company, Schenectady, N. Y. In 1917 he was transferred to the power and mining engineering department of that company, and was appointed to the Syracuse offices in 1923.

D. J. DeBoer (A'34) formerly assistant electrical engineer, Sargent and Lundy, Inc., Chicago, Ill., recently was appointed chief electrical engineer of the Loup River Public Power District, Columbus, Nebr. Mr. DeBoer is a native (1897) of Corsica, S. D., and an electrical engineering graduate (1922) of South Dakota State College. He has been associated with the Sargent and Lundy firm, directly and indirectly, since 1927.

W. B. Rittenhouse (A'03) for many years associated with H. M. Byllesby and Company and the Byllesby Engineering and Management Corporation, Chicago, Ill., has been appointed assistant manager of the engineering division of the Public Utility Engineering and Service Corporation, successor to the Byllesby Engineering and Management Corporation.

F. H. Lane (M'23) for 19 years manager of engineering and construction for the Byllesby Engineering and Management Corporation, Chicago, Ill., has been appointed manager of the engineering division of the Public Utility Engineering and Service Corporation, successor to the Byllesby organization, with which Mr. Lane has been associated continuously since 1904.

H. L. Hazen (A'26) assistant professor of electrical engineering at Massachusetts Institute of Technology, Cambridge, recently was made associate professor. Professor Hazen, a graduate of that institution, was employed by the General Electric Company at Schenectady, N. Y., for a year prior to joining the faculty in 1925.

A. B. Berresford (A'31) an electrical engineering graduate (1929) of Cornell University, recently passed the examinations of the National Board of Medical Examiners and expects to enter the general practice of medicine at Ithaca, N. Y., in the near future.

Peter Fries, Jr. (A'34) an electrical engineering graduate (1933) of the College of the City of New York, recently was admitted to the bar of the State of New York, and has opened offices for the general practice of law at New York, N. Y.

G. A. Price (A'33) formerly employed in the engineering department of the Susquehanna Silk Mills, Sunbury, Pa., now is employed as general draftsman for the Hygrade Sylvania Corporation, St. Marys, Pa.

H. A. Warren (A'36) formerly a draftsman for the Florida Mapping Project, Gainesville, now is an electrical maintenance engineer for the United Clay Mines Corporation, Trenton, N. J.

G. E. Mullin, Jr. (A'36) sales engineer, General Electric Company, Indianapolis, Ind., has been transferred to the rural electrification section of that company at Schenectady, N. Y.

T. S. Baker (A'28) formerly chief engineer, Press Wireless, Inc., Hicksville, N. Y., recently was appointed superintendent of radio construction for the U.S. Signal Corps, with headquarters at Washington, D. C.

L. H. Dee (A'36) has resigned his position with Fairbanks, Morse, and Company, New York, N. Y., to become associated with Standard Air Conditioning, Inc., New Rochelle, N. Y.

H. A. Boyce (A'34) formerly division transmission engineer, American Telephone and Telegraph Company, Cleveland, Ohio, has been transferred to the Cincinnati, Ohio, offices of that company.

G. M. Coffman (A'35) formerly a radio engineer for the George W. Taylor Company, Williamson, W. Va., now is employed by the American Rolling Mill Company, Ashland, Ky.

C. M. Mackey (A'34, M'36) manager of the Oklahoma City (Okla.) branch of the Westinghouse Electric Supply Company, has been transferred to the Houston, Texas, offices of that company.

B. P. Rucker (A'03, F'13) engineer, Federal Power Commission, Washington, D. C., recently was transferred to the Atlanta, Ga., regional offices of the Federal Power Commission.

R. D. Goodrich (A'33) formerly an electric dredge engineman, U.S. Engineers, Fort Peck, Mont., now is a junior hydraulic engineer with the U.S. Geological Survey, St. Louis, Mo.

M. L. Khanna (A'31) formerly a student engineer for The Vilter Manufacturing Company, Milwaukee, Wis., has been transferred to Lahore, India, as a representative of that company.

R. W. Rhodes (A'23) who has been an electrical engineer for Charles H. Tenney and Company, Boston, Mass., now is with the New England Power Service Company, Worcester, Mass.

T. L. Berri (A'35) formerly a junior engineer, Southwestern Light and Power Company, Lawton, Okla., now is employed in the relay department of the Public Service Company of Colorado, Denver.

U. N. Halliday (A'28) formerly district manager, Pacific Electric Manufacturing Corporation, San Francisco, Calif., now is employed by the John Roebling's Sons Company, Los Angeles, Calif.

Obituary

Edward Barnard Meyer, of Newark, N. J., junior past-president of the Institute, died January 30, 1937, just as these pages were going to press. For additional information, see the March issue of Electrical Engineering.

Frank Arthur Laws (A'09, M'12, F'28) emeritus professor of electrical measurements, Massachusetts Institute of Technology, Cambridge, died in November 1936. Professor Laws was born May 28, 1867, at North Bridgewater, Mass., and was graduated from Massachusetts Institute of Technology in 1889, with the degree of bachelor of science, following which he was retained on the faculty as an assistant in physics. In 1891 he was made an instructor in physics, and in 1894 an instructor in electrical measurements. From 1897 until 1902 he served as assistant professor of physics before being appointed assistant professor of electrical testing. In 1906 he was appointed associate professor of electrical testing, and continued in that capacity until 1913, when he received a professorship of electrical engineering. He was retained at that time by the Massachusetts Gas and Electric Commission to make tests of electric meters, and later performed special work in electrical measurements for the Edison Electric Illuminating Company of Boston, the General Electric Company, and various electric light and power companies throughout New England. He was appointed professor of electrical measurements in 1921. Professor Laws was the author of many technical papers dealing with the subject of electrical measurements, and on that subject prepared a textbook, which became widely used and acknowledged to be one of the leading textbooks of its kind in the English language. He served the Institute during 1917–19 and 1920–22 as a member of the committee on standards, and during 1929–33 as a member of the committee on instruments and measurements. He was a member of the National Electric Light Association and a fellow of the American Academy of Arts and Sciences.

William Benjamin Jackson (A'97, M'98, F'13, Life Member, past vice-president) retired rate consultant to The New York Edison Company, New York, N. Y., died January 20, 1937. Colonel Jackson was born June 23, 1870, at Kennett Square, Pa., and was graduated from Pennsylvania State College in 1890 with the degree of bachelor of science; he received the degree of mechanical engineer from the same institution in 1895. After serving with several companies from 1890 to 1894, he was employed by The United Electric Light and Power Company, New York, N. Y., as an inspector, but shortly thereafter entered the testing department of the Stanley Electric Manufacturing Company at Pittsfield, Mass., and finally became assistant to the chief engineer of that company. In 1895 Colonel Jackson became manager of the Lowell (Mich.) Water and Light Company, and in 1897 he accepted a similar position with the Peninsular Light and Power Company, Grand Rapids, Mich. During 1898–99 he was chief engineer and superintendent of the New York and Staten Island Electric Company and consulting engineer of the Staten Island Electric Railway Company; from 1899 to 1901 he served as chief engineer and superintendent of the Colorado Electric Power Company, Cripple Creek. Beginning in 1901, and for 2 years thereafter, he was special engineer abroad for the Stanley Electric Manufacturing Company, and from 1903 until 1918 Colonel Jackson was a member of the consulting engineering firm of D. C. and William B. Jackson, of New York. He served The New York Edison Company from 1919 until his retirement in 1933. He presented many papers before the Institute and was a member of several of the technical committees; in addition, he served as the Institute's manager from 1912 to 1915 and as a vice-president during 1918–19. He was a member of the American Society of Civil Engineers, Society of American Military Engineers, and The American Society of Mechanical Engineers.

Albert T. Perkins (M'25, Life Member) consulting tranportation engineer, St. Louis (Mo.) Union Trust Company, died November 22, 1936. Colonel Perkins was born October 2, 1865, at Brunswick, Me., and received the degree of bachelor of arts at Harvard University in 1887; he also received the honorary degree of master of arts from Harvard University in 1919. Following his graduation, he entered the employ of the Chicago, Burlington, and Quincy Railroad Company, and during the period 1887–96 held various positions in that company. From 1897 to 1902 he was superintendent of terminals in the St. Louis division of that company, and from 1902 until 1906 held a similar position in the St. Joseph division. In 1906 Colonel Perkins became consulting engineer and railroad adviser to the St. Louis Union Trust Company, and served in that capacity continuously for 30 years; however, he served at the same time as president of the Brownsville and Matamoros Bridge Company; Marshall and East Texas Railway Company; Chicago, Milwaukee, and Gary Railway Company; New Iberia and Northern Railway Company; Appalachicola Northern Railroad Company; and the West Texas Abstract and Guarantee Company. In addition, he was consulting engineer for the Southern Traction Company of Texas and manager for the receiver of the United Railways Company of St. Louis. Colonel Perkins had a brilliant military record during the World War and was awarded the Distinguished Service Medal and the British Order of St. Michael and St. George.

Thomas Edward Penard (A'08) assistant superintendent, station engineering department, Edison Electric Illuminating Company of Boston, Mass., died October 27, 1936. Mr. Penard was born May 7, 1878, at Paramaribo, Dutch Guiana, and was graduated in electrical engineering at the Massachusetts Institute of Technology in 1900, following which he was engaged briefly as a draftsman for 2 structural companies before becoming associated with the Edison Electric Illuminating Company of Boston in 1901. His first position with that company was as a draftsman, but he later became an electrical engineer, and in that capacity was active in the design of the company's electrical systems. He became assistant superintendent of the station engineering department in 1931. Mr. Penard was active in education work, having served as instructor and superintendent of several evening schools in Boston, and for a time was dean of the evening school of Northeastern University. He served the Institute as a member of the committees on industrial and domestic power (now general power applications), 1920–21, and instruments and measurements, 1927–29.

Arthur John Ralph (A'22, M'31) technician in the electrical engineering department of Yale University, New Haven, Conn., died February 11, 1936, according to word just received at Institute headquarters. Mr. Ralph was born February 23, 1861, at Berkshire, England, and received his electrical training by serving an apprenticeship in the philosophical instrument trade in England. He came to the United States in 1889 and entered the instrument department of the Schuyler Electric Company, Middletown, Conn., in 1890. When the General Electric Company absorbed the

Schuyler Electric Company in 1892, Mr. Ralph was placed in charge of the experimental laboratory of the Middletown works, where he remained until he accepted a position as superintendent of the New Haven, Conn., plant of The Walker Electric Company. In 1898 the Walker Electric Company was absorbed by the Westinghouse Electric & Manufacturing Company, and Mr. Ralph was retained as assistant in the detail department of the New Haven plant. He remained in that position until 1900, when he became factory superintendent of the Kidder Motor Vehicle Company, New Haven. In 1904 he became head of the assembling department of the Connecticut Computing Machine Company, New Haven, and in 1911 a designer of automatic ammunition machinery for the Winchester Rifle Company. He joined the staff of Yale University as technician in the electrical department in 1916.

Charles Joyce Russell (A'04, member for life) vice-president in charge of rates and standard practice of the Philadelphia (Pa.) Electric Company, died December 8, 1936. Mr. Russell was born March 10, 1864, at Norway, Me., and attended the Lawrence Scientific School and Massachusetts Institute of Technology. In 1886 he became associated with the Holtzer Cabot Electric Company, where he did general electrical installation and storage battery work. After serving for one year as superintendent of the H. B. Cutter Company, Philadelphia, and a similar period as superintendent of the electrical department of the Tacony Iron and Metal Company, Philadelphia, he became superintendent of the Manufacturers Electric Company in 1891. In 1899 Mr. Russell became superintendent of the combined Manufacturers and Suburban Electric Companies, retaining that position until the companies were absorbed by the Philadelphia Electric Company in 1904, when he became district manager. He retained that position until he was appointed vice-president in charge of the commercial department in 1925; later he became vice-president in charge of rates and standard practice.

Francis Eugene Donohoe (A'06, member for life) special representative, General Cable Corporation, New York, N. Y., died December 2, 1936. Mr. Donohoe was born October 28, 1863, at Lowell, Mass., and received his education in the public schools of Boston, Mass. He started his technical career in the experimental laboratories of the American Bell Telephone Company, Boston, Mass., and after 3 years of service with that company, joined the Edison General Electric Company as a salesman in 1889. In 1891 he became associated with the Safety Insulated Wire and Cable Company, New York, N. Y., where he remained for 3 years before accepting the position of western manager of the American Electrical Works, Chicago, Ill., in 1894. In 1906 Mr. Donohoe was appointed eastern sales manager of the same company, and was transferred to New York, N. Y., where in 1913 he became sales manager of the National Conduit and Cable Company. In 1925 he returned to the employ of the Safety Insulated Cable and Wire Company as special agent, and when that company was merged with another to form the General Cable Corporation, Mr. Donohoe was retained in the same capacity in the new company.

David Henry Kelly (A'17) district manager, Allis-Chalmers Manufacturing Company, Philadelphia, Pa., died December 7, 1936. Mr. Kelly was born at Steubenville, Ohio, July 2, 1883, and attended the University of Illinois, where he was graduated with the degree of electrical engineer in 1904. After a brief period of employment with the El Paso Smelting and Refining Company, he entered the employ of the Bullock Electric Manufacturing, Company, Norwood, Ohio, at about the time that company became a part of the Allis-Chalmers Company. Mr. Kelly served as sales engineer in that company's Cincinnati (Ohio), Philadelphia (Pa.), and Washington (D. C.) offices, and at the conclusion of his service in the World War was transferred to the New York, N. Y., offices. He had been manager of the Philadelphia offices since 1920. He was active in local Institute affairs, and was chairman of the Philadelphia Section during 1930–31.

Lester Robley Sailer (A'31, M'36) instructor in electrical engineering, Columbia University, New York, N. Y., died December 13, 1936. Mr. Sailer was born July 14, 1906, at New York, N. Y., and received the degrees of bachelor of arts (1929), bachelor of science in electrical engineering (1930), and electrical engineer (1935) at Columbia University. Following his graduation in electrical engineering, he was appointed an instructor in electrical engineering, at Columbia University, and was retained in that position continuously; he also served as an assistant in physics for the 3 scholastic years during 1927–30. In addition to his regular teaching duties, Mr. Sailer undertook consulting engineering assignments from several commercial organizations in New York, N. Y., and from Columbia University. He was a member of the Society for the Promotion of Engineering Education.

Charles V. Woodward (A'24) manager of the Baltimore, Md., offices of the Westinghouse Electric & Manufacturing Company, died November 19, 1936. Mr. Woodward was born July 23, 1878, and received his formal technical education at Pennsylvania State College. Upon completion of his studies he entered the employ of the Westinghouse Electric & Manufacturing Company at the East Pittsburgh, Pa., works in 1906, but was transferred in 1909 to the Philadelphia, Pa., offices, where he specialized in transportation and power engineering. He was identified with the development of several light traction companies in the state of Pennsylvania. In 1923 Mr. Woodward was transferred to the Baltimore offices of the Westinghouse company in the capacity of manager, which position he retained continuously for 13 years.

Albert George Thomas Goodwin (A'20) chief electrical engineer, The Broken Hill Proprietary Co., Limited, Newcastle, N. S. W., Australia, died November 12, 1936. Mr. Goodwin was born July 6, 1893, at Melbourne, Vic., Australia, and received his technical education at Working Men's College (Australia). In 1910 he was apprenticed to the Melbourne Electric Supply Company, and after having served in the field positions of shift engineer and technical assistant, was made a station superintendent. In 1917 Mr. Goodwin was employed by The Broken Hill Associated Smelters, as assistant to the power plant erecting engineer, and in the following year was made power plant engineer in charge of plant. Later he was transferred to the iron and steel works of The Broken Hill Proprietary Co., Limited, and eventually became chief electrical engineer.

Louis Ferdinand Reinhard (A'10, M'13, F'20) sales engineer, Geuder, Paeschke & Frey Co., Milwaukee, Wis., died in June 1936, according to word just received at Institute headquarters. Mr. Reinhard was born at Milwaukee, October 1, 1884, and was graduated in electrical engineering from the University of Wisconsin in 1907. Immediately following his graduation, he entered the engineering department of the Mechanical Appliance Company, Milwaukee, and was appointed chief engineer of that company in 1909. He remained in that position until 1920, when he accepted a position as engineer with Geuder, Paeschke & Frey Co. Later Mr. Reinhard was made a sales engineer, and eventually became sales manager in the contract stamping division of that company.

Francis Raymond Welles (A'87, member for life) retired, Altadena, Calif., died December 14, 1936, at Vernet-les-Bains, France. Mr. Welles was born at Athens, Pa., in 1854, and was graduated from the University of Rochester in 1875 with the degree of bachelor of arts. During the 5 years following his graduation, he was associated in business with E. M. Barton (A'87) founder of the Western Electric Company, and in 1880 left the United States to establish factory branches of that company in foreign lands. In 1882 he formed the first branch at Antwerp, Belgium, where the first multiple telephone switchboard used in Europe was manufactured. Mr. Wells served as manager of that branch until he retired in 1913.

John Jenkinson (A'22) superintendent of the meter department of the British Columbia Electric Railway Company, Ltd., Vancouver, died October 14, 1936, according to information received at Institute headquarters. Mr. Jenkinson was born April 20, 1870, at Askan, Lancashire, England, and received his formal education in that country. In 1898 he went to Canada and accepted a position with the British Columbia Electric Railway Company, Ltd., where he remained continuously for 38 years. He was in complete charge of the meter department of that company from the time of its establishment.

Membership

Recommended for Transfer

The board of examiners, at its meeting on January 20, 1937, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the national secretary.

To Grade of Member

Aiken, E. H., supervisor of division of operations, District 5, Works Progress Administration, San Bernardino, Calif.
Davis, F. E., engineer, Commonwealth and Southern Corporation, Jackson, Mich.
Greenfield, E. W., cable research engineer, Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y.
Hall, Sherman M., assistant manager, statistical bureau, Consolidated Edison Company, New York, N. Y.
Hase, R. C., transmission engineer, Southwestern Bell Telephone Company, St. Louis, Mo.
Isenberg, H. D., vice-president, Federal Insulation Company, Chicago, Ill.
Karsten, E. J., electrical engineer, United Light and Power Engineering and Construction Company, Kansas City, Mo.
Langdell, J. C., engineer, Commonwealth and Southern Corporation, Jackson, Mich.
Leslie, J. O., operating electrical engineer, E. M. Gilbert Engineering Corporation, Reading, Pa.
Likel, H. C., chief engineer, Pacent Engineering Corporation, New York, N. Y.
MacGillivray, A. L., telephone engineer, Western Electric Company, New York, N. Y.
McDowell, L. G., assistant engineer, New York and Queens Electric Light and Power Company, Flushing, N. Y.
Petit, F. W., assistant engineer, Brooklyn Edison Company, Inc., Brooklyn, N. Y.
Platt, C. J., Jr., superintendent, service inspection bureau, New York Edison Company, Inc., New York, N. Y.
Siskind, R. P., assistant professor of electrical engineering, Harvard University, Cambridge, Mass.
Smith, W. A., consulting engineer, Jacksonville, Fla.
Sommerman, G. M. L., research engineer, American Steel and Wire Company, Worcester, Mass.
Underhill, J. E., assistant engineer, British Columbia Electric Railway Company, Vancouver, B. C., Canada.
Van Sickle, R. C., engineer, switchgear engineering department, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

19 to Grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the national secretary before February 28, 1937, or April 30, 1937, if the applicant resides outside of the United States or Canada.

Abbott, E. G., General Electric Company, Chicago, Ill.
Andersen, J. R. (Member), New York and Queens Electric Light and Power Company, Flushing, N. Y.
Anderson, H. C., Oregon State Highway Commission, Salem, Ore.
Anderson, N. E., Homestake Mining Company, Lead, S. D.
Angevine, O. L. Jr., Stromberg-Carlson Telephone Manufacturing Company, Rochester, N. Y.
Ashe, F. C. (Member), Carnegie Institute of Technology, Pittsburgh, Pa.
Atwood, E. M., Washington Water Power Company, Troy, Idaho
Bacon, F. S., Jr., Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.
Baranovsky, C., J. R. Longstaffe, Ltd., Toronto, Ont., Canada
Barrows, W. M., Public Service Electric and Gas Company, Hackensack, N. J.
Bennett, R. M., General Electric Co., Schenectady, N. Y.
Bernhard, G. K., Ohio Power Company, Canton, O.
Bissiri, A. Jr., 2409 Silver Lake Drive, Los Angeles, Calif.
Blaese, A. C., Porcelain Products, Inc., Chicago, Ill.
Boast, W. B., Iowa State College, Ames, Iowa.
Bobe, C. P. (Member), 1530 Olive Street, St. Louis, Mo.
Boehmer, F. D., Louis Allis Company, Milwaukee, Wis.
Bosworth, P. N., General Electric Company, Schenectady, N. Y.
Bower, G. L., Crane Company, Chicago, Ill.
Brandenburger, L., Wagner Electric Corporation, Salt Lake City, Utah.
Brigham, F. W., Washington Pulp and Paper Company, Port Angeles, Wash.
Bromley, J. E., Public Service Commission, New York, N. Y.
Brown, C. A., Southern California Telephone Company, Los Angeles, Calif.
Brown, S. S., Brown Brockmeyer Company, Dayton, O.
Bullock, E. S., Federal Power Commission, Atlanta, Ga.
Capy, P. L., 725 Paulus Street, Dallas, Texas.
Carlson, A. B., Southern New England Telephone Company, New Haven, Conn.
Carlson, H., Associated Press, New York, N. Y.
Casiano, L. J., Carnegie Illinois Steel Corporation, Youngstown, O.
Clasgens, A. E., New York State Electric and Gas Corporation, Brewster, N. Y.
Clifford, L. V., General Electric Company, Philadelphia, Pa.
Collings, L. W. Jr., General Electric Company, Schenectady, N. Y.
Coons, T., Potomac Electric Power Company, Washington, D. C.
Crates, R. R., Memphis Light and Water Commission, Tenn.
Craven, W. D., New York and Queens Electric Light and Power Company, Flushing, N. Y.
Croden, W. T., Metropolitan Water District, Banning, Calif.
Cutler, L. B., Armstrong Cork Products, Boston, Mass.
Davies, M. (Member), Langley Manufacturing Company, Ltd., Vancouver, B. C., Canada
Davis, E. W. (Member), 1478 Municipal Building, New York, N. Y.
Davis, M. F., Young Men's Christian Association, Zanesville, O.
Davis, P. C., Donnelly Electric and Neon Company, Boston, Mass.
de Anda, E., El Paso Electric Company, El Paso, Texas
Decker, H. D., Consolidated Edison Company, New York, N. Y.
Dillon, D. A., Century Electric Co., St. Louis, Mo.
Dorey, F. M., General Electric Company, Schenectady, N. Y.
Dumser, W. T., International Business Machines Corp., Chicago, Ill.
Durst, N. J., Cincinnati and Suburban Bell Telephone Company, Ohio.
Ellis, E. A., Boston and Maine Railroad, Billerica, Mass.
Emery, W. L., University of Utah, Salt Lake City, Utah.
Esval, O. E., Sperry Gyroscope Company, Inc., Brooklyn, N. Y.
Evans, A. J., Public Service Commission, New York, N. Y.
Evans, L. M., Worthington Pump and Machinery Corporation, Buffalo, N. Y.
Everest, F. A., Oregon State College, Corvallis.
Eysenbach, H. A., Crouse-Hinds Company, Syracuse, N. Y.
Fein, H., Belyea Company, Inc., New York, N. Y.
Ferrell, J. T., Brooklyn Edison Company, Brooklyn, N. Y.
Finley, A. R., Reliance Electric and Engineering Company, Cleveland, Ohio.
Fisher, R. L., Emerson Electrical Manufacturing Company, St. Louis, Mo.
Forsyth, W. H., Florida City, Fla.
Fowles, G. A., Anaconda Wire and Cable Company, Pawtucket, R. I.
Fox, E. L., 715 Sanford Street, Peoria, Ill.
Fraser, J. D., Jersey Central Power and Light Company, Allenhurst, N. J.
Frieseke, A. H., Southern Line Material Company, Birmingham, Ala.
Frith, J. M., American Telephone and Telegraph Company, New York, N. Y.
Fuller, J. L., Reliance Electric and Engineering Company, Cleveland, O.
Gago, F. J., University of Florida, Gainesville, Fla.
Gallagher, F. W., Franklin Institute, Philadelphia, Pa.
Ganzar, J. A., Carnegie Illinois Steel Corporation, Gary, Ind.
Gaynor, A. M., I. Gaynor, Inc., New York, N. Y.
Getting, M., Jr., Allis-Chalmers Manufacturing Company, Pittsburgh, Pa.
Gissel, E. A., Central Arizona Light and Power Company, Phoenix, Ariz.
Glas, F. J., New York and Queens Electric Light and Power Company, Flushing, N. Y.
Gordy, T. D., General Electric Company, Pittsfield, Mass.
Gosney, W. A., Trumbull Electrical Manufacturing Company, Ludlow, Ky.
Greentree, C. D., General Electric Company, Schenectady, N. Y.
Griesinger, F. D., Buffalo General Electric Company, Buffalo, N. Y.
Hamilton, J. P., Tennessee Valley Authority, Wilson Dam, Ala.
Hamilton, R. A., University of British Columbia, Vancouver, Canada.
Hansen, A. Jr., General Electric Company, Schenectady, N. Y.
Harris, C. S., Federal Telegraph Company, Newark, N. Y.
Hemmerich, F. J., New York and Queens Electric Light and Power Company, Flushing, N. Y.
Hepler, M. M., Textile Machine Works, Reading, Pa.
Hertel, R. F., General Electric Company, Schenectady, N. Y.
Higbee, C. W. (Member), United States Rubber Company, New York, N. Y.
Hillman, E. C., 815 Crotona Park North, New York, N. Y.
Hine, C. R., Pennsylvania Railroad, Wilmington, Del.
Houle, A. U., University of Toronto, Ont., Can.
Howell, J. C., Public Service Electric and Gas Company, Irvington, N. J.
Hufford, G. V., Century Electric Company, St. Louis, Mo.
Hughes, E. T., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Hunt, F. B., Green Mountain Power Corporation, Wells River, Vermont
Hunt, R. McP., General Electric Company, Schenectady, N. Y.
Hutchcraft, H. W., Tennessee Valley Authority, Wilson Dam, Ala.
Imle, H. R., Carter Oil Company, Tulsa, Okla.
Johnson, J. S., Iowa State College, Ames.
Johnson, S. E., General Electric Company, Oakland, Calif.
Jones, J. N., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Kaup, J. A., Doble Engineering Company, Medford Hillside, Mass.
Kelly, C. M. Jr., Guided Radio Corporation, New York, N. Y.
Kennedy, L. F., General Electric Company, Philadelphia, Pa.
King, H. W., New York (N. Y.) Edison Company, Inc.
Kirby, R. N., Deming Ice and Electric Company, Deming, N. M.
Kirkpatrick, P. E., Montreal Engineering Company, Ltd., Regina, Sask., Canada.
Kyle, W. D. Jr., Milwaukee, Wisconsin Electric Railway and Light Company.
Lank, W. J., Potomac Electric Power Company, Washington, D. C.
Larson, S. R., Jackson and Moreland, Boston, Mass.
Lear, T. J., New York and Queens Electric Light and Power Company, Long Island City, N. Y.
Lester, S. L., Transducer Corporation, New York, N. Y.
Levine, L. J., Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.
Lightfoot, T. C. (Member), General Electric Company, Philadelphia, Pa.
Lillybridge, C. R., U. S. Bureau of Reclamation, Boulder City, Nevada.
Lockett, H. E., General Electric Company, Philadelphia, Pa.
Logan, J. E., Jersey Central Power and Light Company, Allenhurst, N. J.
MacCutcheon, R. H., Western Reserve University Law School, Cleveland, O.
Marsh, R. H., Southern California Edison Company, Ltd., Los Angeles, Calif.
Martens, J. J., New York and Queens Electric Light and Power Company, Jamaica, N. Y.
Matson, D. L., Jr., 101 Fifth Avenue, New York, N. Y.
Matthew, M. P., General Electric Company, Schenectady, N. Y.
Mauritz, F. E., General Electric Company, Schenectady, N. Y.
Maxwell, A. (Fellow), Edison Electric Institute, New York, N. Y.
McGee, H. M., Pennsylvania Power and Light Company, Sunbury, Pa.
McLean, L. V., Louisiana State University, Baton Rouge.
McNamara, C., Commonwealth Edison Company, Chicago, Ill.
Meehan, J. M. Jr., 12–14 West 37th Street, New York, N. Y.
Meudell, A. Y. Jr., General Electric Company, Schenectady, N. Y.
Miller, E. F., American Telephone and Telegraph Company, New York, N. Y.
Misenheimer, H. N. (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Mohan, A. R., 58 Hammond Street, Cambridge, Mass.
Montgomery, W. D., Cincinnati and Suburban Bell Telephone Company, Norwood, O.
Moon, A. W., New York State Transit Commission, New York, N. Y.
Moore, P., Hancock Brothers, San Francisco, Calif.
Muller, H. N. Jr., Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.
Mundt, O. T., Montana Dakota Utilities Company, Williston, N. D.
Nason, H. E., Westinghouse Electric & Manufacturing Company, Chicago, Ill.
Nicholson, J. R., General Electric Company, Schenectady, N. Y.
Norton, V. E., General Controls Company, Minneapolis, Minn.
Oldfield, R. T. (Member), Public Service Commission, New York, N. Y.

sborn, R. M., Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
senbaugh, C. L., Light and Water Division, City of Memphis, Tenn.
'Shea, C. L., Curtis Lighting, Inc., New York, N. Y.
almer, L. T., Burns and McDonnell Engineering Company, Kansas City, Mo.
arrott, J. A. (Member), American Telephone and Telegraph Company, New York, N. Y.
artington, R. M., General Electric Company, Pittsfield, Mass.
awluk, J., Sarvas Electric Company, Brooklyn, N. Y.
ipes, L. A., Rice Institute, Houston, Texas.
oey, C. D. (Member), New York and Queens Electric Light and Power Company, Long Island City, N. Y.
ollyea, M. H., C. J. Tagliabue Manufacturing Company, Brooklyn, N. Y.
ope, R., Bell Telephone Laboratories, Inc., New York, N. Y.
ugh, H. C., Cast Iron Pipe Company, Birmingham, Ala.
atliff, A. H., Oklahoma Gas and Electric Company, Shawnee, Okla.
azovsky, A. M., Laclede Gas Light Company, St. Louis, Mo.
elson, M., National Park Service, Washington, D. C.
hodes, W. E., Stone and Webster Engineering Company, Richmond, Va.
owe, I., 652 Lafayette Avenue, Brooklyn, N. Y.
oby, F. H., 710 South 3rd Street, Milwaukee, Wis.
oehmann, L. F. (Member), 310 West 113th Street, New York, N. Y.
ogers, E. T., Bishop Wire and Cable Corporation, New York, N. Y.
utledge, G. A., Allis-Chalmers Manufacturing, Company, Pittsburgh, Pa.
anders, J. W., Long Island Lighting Company, Roslyn Heights, N. Y.
antiago, F., Aldrich Pump Company, Allentown, Pa.
chroedel, H. E., Chicago, Milwaukee, St. Paul, and Pacific Railroad, Milwaukee, Wis.
immons, H., Georgia Power Company, Atlanta.
itkin, A., Century Lighting Equipment, Inc., New York, N. Y.
koog, A. W., Kingsbury Machine Tool Corporation, Keene, N. H.
lusser, J. A., National Broadcasting Company, Inc., Denver, Colo.
mith, P. D., Cansfield Electrical Works, Toronto, Ont., Canada.
okasits, F. M., Gibbs and Hill, New York, N. Y.
parrow, K. M., Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.
tafford, A. B., Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.
teinmetz, C. L., General Controls Company, Minneapolis, Minn.
tratford, J. P., 821 North Normandie Avenue, Los Angeles, Calif.
ukava, L., Reno Gold Mines, Ltd., Salmo, B. C., Canada.
wanson, M. C. W., American Locomotive Company, Schenectady, N. Y.
'aborelli, R. V., 512 14th Street, Union City, N. J.
'aylor, O. L., Arrow-Hart and Hegeman Electric Company, Hartford, Conn.
'yvand, J. A. (Member), Iowa Farm Bureau Federation, Des Moines, Iowa.
Ipham, N. C., General Electric Company, Lynn, Mass.
'an Winkle, E. W., Best Manufacturing Company, Inc., Irvington, N. J.
on Roeschlaub, F., General Electric Company, Schenectady, N. Y.
Vagner, E., 6235 West Roosevelt Road, Berwyn, Ill.
Valter, J. H., Milwaukee (Wis.) Electric Railway and Light Company.
Vatkins, D. L., American Steel and Wire Company, Worcester, Mass.
Vay, K. J., Bell Telephone Laboratories, Inc., New York, N. Y.
Vells, F. B., Stone and Webster Engineering Corporation, Richmond, Va.
Vells, R. M., New York and Queens Electric Light and Power Company, Flushing, N. Y.
Vest, F. L., Niagara, Lockport, and Ontario Power Company, Buffalo, N. Y.
Vhite, J. C., Air Reduction Sales Company, Corning, N. Y.
Vilcox, H. L. (Member), Electric Controller and Manufacturing Company, Cleveland, O.
Vilke, E. A., 6025 Melrose Avenue, Chicago, Ill.
Villiams, S. B. (Member), *Electrical World*, New York, N. Y.
Vinkelman, H. T., Jr., City of Memphis (Tenn.), Water and Light Division.
Vuerch, L. W., City of Tacoma, (Wash.), Public Utilities.
Vopat, R. M., Iowa Continental Telephone Company and Interior Telephone Company, Grinnell, Iowa.
Vyckoff, P. H., California Institute of Technology, Pasadena.
immer, C. S., Bussmann Manufacturing Co., St. Louis, Mo.

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edil, S. D., Public Works Department, Electricity Branch, Lahore, India.
hat, V. D., 50 New Street Vepery, Madras, India,
ordero, C. L., Puerto Rico Reconstruction Administration, Guayama.
Desai, N. N., c/o AEG India Electric Company, Ltd., Bombay, India.
Fukushima, K., Shibaura Engineering Works, Ltd., Yokohama, Japan.
Jadeja, K. R. (Member), Nawanagar State Power House, Jamnagar, India
Kumar, C. R., Electrical Supply Companies, Ltd., Cuttack, India
Meneghelli, H. A., 4 Calle Oriente number 38, San Salvador, El Salvador.
Miyamoto, c/o S., Shibaura Engineering Works, Yokohama, Japan.
Murray, H. H. Jr., Compañia Eléctrica de Santo Domingo, Ciudad Trujillo, Dominican Republic.
Napper, R. E. (Member), Booker Brothers, McConnell and Company, Ltd., Georgetown, British Guiana.
Suryabandara, A. V., Government Electrical Undertakings, Colombo, Ceylon.

12 Foreign

Addresses Wanted

A list of members whose mail has been returned by the postal authorities is given below, with the addresses as they now appear on the Institute record. Any member knowing of corrections to these addresses will kindly communicate them at once to the office of the secretary at 33 West 39th St., New York, N. Y.

Burns, Arthur E., 1958 E. 29th St., Brooklyn, N. Y.
Eiler, E. E., 101 Brookline Court, Upper Darby, Pa.
Godoy, Ernesto R., Cia. Tel. y Tel. Mex., 16 de Septiembri No. 13, Mexico, D. F., Mex.
Jones, Harry Kenneth, 5511 Kenmore Ave., Chicago, Ill.
Koch, Joseph Stanley, 11 Howe Ave., New Rochelle, N. Y.
Little, Leroy C., 3414—17th St., N., Cherrydale, Va.
Ludwig, Leon R., 434 Burling Road, Forest Hills, Pittsburgh, Pa.
Millheisler, Charles A., 1417 Catalpa Ave., Chicago, Ill.
Miyota, Nath S., 916½ Howell St., Seattle, Wash.
Moore, Everett, 821 Sunset Blvd., Los Angeles, Calif.
Peach, Paul S., Upperville, Va.
Pollastro, John B., Helper, Utah.
Sawyer, Fred E., 811 E. Wisconsin Ave., Milwaukee, Wis.
Wong, Harry Y. L., 771 Broadway, West New York, N. J.

14 Addresses Wanted

Engineering Literature

New Books in the Societies Library

Among the new books received at the Engineering Societies Library, New York, recently, are the following which have been selected because of their possible interest to the electrical engineer. Unless otherwise specified, books listed have been presented gratis by the publishers. The Institute assumes no responsibility for statements made in the following outlines, information for which is taken from the preface of the book in question.

ELECTRICAL ENGINEERING in RADIOLOGY. By L. G. H. Sarsfield and V. E. Pullin. Pittsburgh, Instruments Publishing Co., 1936. 284 p., illus., 9x6 in., cloth, $6.00. Deals exclusively with the electrical engineering aspects of X-ray equipment for engineers not familiar with the work.

CONTROL of ELECTRIC MOTORS. By P. B. Harwood. N. Y., John Wiley and Sons, 1936. 390 p., illus., 9x6 in., lea., $4.50. Describes the characteristics of various types of motors and explains how they are used for purposes of control. Discusses the design, construction, and operating characteristics of controllers.

PHYSICAL CONSTANTS of PURE METALS. Ed. by National Physical Laboratory. Lond., His Majesty's Stationery Office, 1936. 27 p., tables, 10x6 in., paper, 6d. (obtainable from British Library of Information, New York, $0.20.) Presents results prepared by the National Physical Laboratory.

Engineering Societies Library

29 West 39th Street, New York, N. Y.

MAINTAINED as a public reference library of engineering and the allied sciences, this library is a co-operative activity of the national societies of civil, electrical, mechanical, and mining engineers.

Resources of the library are available also to those unable to visit it in person. Lists of references, copies or translation of articles, and similar assistance may be obtained upon written application, subject only to charges sufficient to cover the cost of the work required.

A collection of modern technical books is available to any member residing in North America at a rental rate of five cents per day per volume, plus transportation charges.

Many other services are obtainable and an inquiry to the director of the library will bring information concerning them.

NATURE of PHYSICAL THEORY. By P. W. Bridgman. Princeton (N. J.) University Press, 1936. 138 p., 9x6 in., cloth, $2.00. Presents a critical analysis of the points of view and methods in trying to understand the simpler aspects taken to be within the domain of physics.

TELEVISION RECEPTION, Construction and Operation of a Cathode Ray Tube Receiver for the Reception of Ultra-Short Wave Television Broadcasting. By M. von Ardenne, translated by O. S. Puckle. Lond., Chapman and Hall, 1936. 121 p., illus., 9x6 in., cloth, 10s. 6d. Intended to stimulate the interest of amateurs in experimentation with television.

TELECOMMUNICATIONS, Economics and Regulation. By J. M. Herring and G. C. Gross. N. Y. and Lond., McGraw-Hill Book Company, 1936. 544 p., illus., 9x6 in., cloth, $5.00. Deals with the economic and public service aspects of the telegraph and telephone industries. Presents the background of development of these industries, deals with the sources of revenue and the factors affecting costs and rate structures. Includes a detailed analysis of the Communications Act of 1934.

ORGANIZATION and MANAGEMENT in Industry and Business. By W. B. Cornell. N. Y., Ronald Press Company, 1936. 802 p., illus., 8x5 in., cloth, $4.50. Aims to provide a course of training in the organization, management, and operation of every department of a business concern.

OLD WIRES and NEW WAVES, the History of the Telegraph, Telephone, and Wireless. By A. F. Harlow. N. Y. and Lond., D. Appleton-Century Company, 1936. 548 p., illus., 9x6 in., cloth, $5.00. A popular history of the origins and development of the telegraph and telephone systems of America. The human side of the story is emphasized.

LESSONS and PROBLEMS in ELECTRICITY. By N. C. Page. N. Y., Macmillan Company, 1936. 356 p., illus., 9x6 in., cloth, $2.75. Based upon a course in the fundamentals of electricity which has been given to sophomore students at Massachusetts Institute of Technology. Planned for students with some training in mechanics and calculus.

HANDBOOK of CHEMISTRY and PHYSICS, 21 ed. Cleveland, Ohio, Chemical Rubber Publishing Company, 1936. 2023 p., 7x4 in., lea., $6.00. The latest annual edition of a well-known reference book.

ELECTRICITY: For Use or for Profit. By B. Ostrolenk. N. Y. and Lond., Harper Brothers, 1936. 211 p., tables, 8x5 in., cloth, $2.00. Discusses one aspect of the power problem: the influence of private utility companies on the standard of living. Considers the social and economic significance of present rate policies.

AUTOMATIC VOLUME CONTROL. ed. and published by J. F. Rider, N. Y., 1936. 94 p., illus., 8x5 in., cardboard, $0.60. Affords a description of the general principles of automatic volume control in radio receivers and of their use in current commercial sets.

ELECTRICAL ENGINEERS' HANDBOOK, 2 volumes (Wiley Engineering Handbook Series, volumes 4 and 5) ed. by H. Pender, W. A. Del Mar and K. McIlwain. 3 ed. N. Y. and Lond., John Wiley and Sons, 1936. illus., 9x5 in., lea. (volume 1, $6.00; volume 2, $5.00). A new edition in 2 volumes; one on power, the other on communications, which may be purchased separately.

Industrial Notes

General Electric Report for 1936.—Orders received by General Electric Co. during the year 1936 amounted to $296,748,219, compared with $217,361,587 during 1935, an increase of 37 per cent. Orders for the quarter ended December 31 amounted to $84,857,181, compared with $58,417,822 for the last quarter of 1935, an increase of 45 per cent.

Reward for "Lost" Meter Socket.—A reward of $50.00 has been offered by the Westinghouse Elec. & Mfg. Co., for the return of the two-millionth type S meter socket. It is properly marked and identified as the two-millionth socket. The finder will be rewarded upon return of the socket to the company at Newark, N. J.

New Cable Accessory.—To meet a widespread demand for a simple and effective device for interconnecting single conductor secondary insulated cables in manholes and vaults, the G & W Electric Specialty Co., Chicago, has developed the "Multitap" which eliminates the use of tape and solder. This splicing device is suitable for cables with or without lead sheath. The copper bus is covered with molded G & W "Resistoyl" oil and moisture resistant rubber compound. The connectors and cable ends are covered with a molded Bakelite insulator sealed at the ends by means of a Resistoyl bushing compressed on the cable with a gland nut. Cable heads are interchangeable and made for all conductor sizes up to 500 mcm. A wrench is the only tool required for installation.

General Electric Expands in Texas.—A 3-story, concrete and brick addition to the General Electric building at Dallas is under construction, adjoining the present office and warehouse building and will provide all departments of the company with permanent headquarters in Dallas. It is expected construction will be completed about June 1. The annex will front 80 ft on Lamar Street and extend 174 ft on Corbin Street. A new $200,000 building in Houston, located on the block recently purchased by the company, bounded by Polk, St. Charles, Clay, and Live Oak Streets, is being erected. The building, of brick and steel construction, will be 2 stories in height and will be used to house the offices, warehouses, and service shops of the General Electric Co., the General Electric Supply Corp., and the General Electric X-Ray Corp.

Factory Built Switchgear Units.—A standard line of factory-built, metal enclosed switchgear, for shipment as a complete assembly, has been announced by the Westinghouse Elec. & Mfg. Co. Suitable for small industrial installations or auxiliary circuits in steam power stations, the units are factory assembled and tested so that cross connections do not have to be made in the field. This metal enclosed switchgear consists of cubicles in which are mounted circuit breakers, buses, disconnecting switches, instrument transformers and similar auxiliaries. On the front panels, which are hinged, are mounted required relay and meter equipment.

New Electric Flow Meters.—The Bristol Co., Waterbury, Conn., announces the addition of a complete line of electric flow meters for steam, liquids, and gases to its line of mechanical flow meters. These flow meters operate on the Bristol Metameter principle of telemetering, which the company has used for several years in instruments to transmit readings of pressure, liquid level, temperature, and motion from the point of measurement to a distant point where they are recorded or indicated on a dial. The electric flow meters can be furnished for recording, integrating, and indicating flow. The readings are transmitted over a simple 2-wire circuit, telephone circuits included, which does not enter into the calibration of the instruments.

Condit Now Allis-Chalmers Unit.—The Allis-Chalmers Mfg. Co., Milwaukee, announces that its subsidiary company, Condit Electrical Mfg. Corp., of Boston, is now operating as a company unit and known as Allis-Chalmers Mfg. Co.—Condit Works. It will continue to specialize in the manufacture of switchgear products as a division of the electrical department under R. S. Fleshiem, manager. The personnel, with headquarters at Hyde Park, will be as follows: George A. Burnham, assistant manager of the electrical department in charge of sales and engineering of the switchgear division; W. S. Edsall, manager of sales, switchgear division; and H. V. Nye, engineer in charge of the switchgear division, with headquarters at Milwaukee. Frank W. Young is works manager.

Trade Literature

Motors.—Bulletin 2-1, 8 pp. Describes single phase motors, repulsion start induction, brush lifting, $^1/_8$ to 40 horsepower. Century Electric Co., 1806 Pine St., St. Louis, Mo.

Connectors.—The "Burndy News," 16 pp., in the form of a tabloid newspaper, profusely illustrated, describes numerous applications of various forms of electrical connectors. Burndy Engineering Co., Inc., 459 East 133rd St., New York City.

Network Equipment.—Bulletin 1184, 8 pp. Describes a complete line of low-voltage, a-c network apparatus, comprising transformers of both vault and subway types, disconnecting and ground switches, and network protectors for all applications. Allis-Chalmers Mfg. Co., Milwaukee, Wis.

Motors.—Illustrated folder, "Making Commutators," describes methods for manufacture, testing and inspection of commutators for d-c motors and generators. Folder, "Making Bobbin-Type Field Coils," illustrates manufacture of field coils for the same apparatus. The Reliance Electric & Engg. Co., 1086 Ivanhoe Road, Cleveland, O.

Insulator Tester.—Catalog 11, Sec. 2, 6 pp. Describes a new device, the "Hipot" insulator tester, a portable outfit for live line testing of individual porcelain insulators in a string or pin type insulator assembly; for operating voltages of 11,000 to 132,000 volts and higher. The equipment consists of three Bakelite sections and a handle section which screw together, an indicating instrument, a ground prod and the necessary cable and connectors. Roller-Smith Co., 233 Broadway, New York City.

Time Delay Relay.—Bulletin 362, 2 pp. Describes a new motor driven time delay relay, in which time ranges start with a maximum of 35 seconds and include $1^3/_4$, $5^1/_4$, $12^1/_4$, $26^1/_4$, 42 and 63 minutes. Differential gearing eliminates the use of troublesome clutches and a magnetically operated brake has been designed for the differential gear train. A standard midget relay, built into the device, provides various load contact combinations including double pole, double throw. The relay is designed for 110 and 220 volt a-c operation, and is immediately recycling. Quick make-and-break contacts are furnished with all contact combinations. Ward Leonard Electric Co., Mt. Vernon, N. Y.

Electrostatic Voltmeters.—Bulletin, 4 pp. Describes a new line of electrostatic voltmeters for a-c and d-c measurements, available in full scales ranging from 150 to 25,000 volts. The instruments are suitable for direct connection on either alternating or direct current for readings up to 3500 volts and are entirely independent of wave form, frequency and temperature. Flush, projecting and portable types may be had in all ranges up to 3500 volts. Applications include cable testing, determining insulator leakage, insulation testing, measuring high impedance circuits, etc. Ferranti Electric, Inc., 30 Rockefeller Plaza, New York City.

Equipment Depreciation Analysis.—A 176-page bulletin on the determination of the probable lives of various types of railroad, public utility and other physical equipment has been published by the Iowa Engineering Experiment Station as Bulletin 125, "Statistical Analyses of Industrial Property Retirements" by Robley Winfrey, research engineer, and will be sent free of charge on request to the Station at Iowa State College, Ames, Iowa. Five methods of constructing survivor curves for the determination of probable life are explained and compared with the "turnover" method. The method of comparison with type curves is simple, accurate, and quickly applied, all in contrast to involved mathematical methods. The bulletin will be helpful to those engaged in depreciation studies.